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ANNUAL MEETING NUMBER

SOCIETY OF AUTOMOTIVE ENGINEERS INC
29 WEST 39TH STREET NEW YORK

-163-

A Car Spring can absorb Shocks, only by Yielding to them. If the Spring is too stiff to yield to a Shock, then it will not Absorb the Shock, but will transmit it directly to the Body and the Passengers.

The above is too elemental to leave room for any argument.

If the car springs are too stiff, the car will ride hard—that's all there is to it.

If a spring which is soft enough to properly absorb shocks "hits bottom," then there is just one thing to do about it—provide more room for spring travel. You can argue long and merrily why you can't provide more spring travel, but the fact remains that until you *do* provide enough spring travel to accommodate the movements of a soft spring, you are going to have a hard riding car.

To overcome hitting bottom by interposing any device or means to stiffen the action of the spring is merely a step which puts you right back again into a condition of hard riding.

Watson Stabilators do not stiffen up the action of the car springs —the required softness of the car spring is in no way interfered with, but is left completely free to rapidly yield to and absorb the shocks. And then, on the return journey (the rebound), Stabilators are immediately on the job with a braking resistance which is automatically metered according to how far the spring has been compressed—according, therefore, to the *force* of the rebound. There is nothing intricate or mysterious about all of the above. Simply garden variety horse sense.

John Warren Watson Company

Original and Sole Manufacturers of Stabilation

Twenty-fourth and Locust Streets

Philadelphia

[Detroit Branch: 3001-3003 Grand Boulevard, East]

WATSON

STABILATORS

They hold in proportion to the need

THE JOURNAL OF THE SOCIETY OF AUTOMOTIVE ENGINEERS

Vol. XVIII February, 1926 No. 2

Chronicle and Comment

Further Discussion Solicited

AT the technical sessions of the recent Annual Meeting it was impossible, owing to lack of time, for all those who desired to discuss the papers to do so. The Meetings Committee earnestly desires that all persons so inclined forward their discussion of any of the papers in writing to Society headquarters, at the earliest possible date.

Summer Meeting at French Lick Springs, Ind.

RETURNS from the recent canvass of the Society's membership gave French Lick Springs, Ind., the position of preference as regards a meeting place for the 1926 Summer Meeting. Inasmuch as over 20 per cent of the Society's membership recorded their wishes, the Meetings Committee and the Council felt that the vote should be given full consideration, and largely upon this basis it was decided to hold this popular event at the above-mentioned resort during the week of the Indianapolis Races. It is felt that this outcome will be greeted with extreme enthusiasm by a large majority.

Additional information in this regard will be found in a report of the session of the Meetings Committee on p. 111, and further announcements will be made in subsequent issues of THE JOURNAL.

Annual Meeting Enthusiastically Received

WITH an unusually large registration and a record-breaking attendance at its technical sessions, the 1926 Annual Meeting has passed into history and will be recorded among the most successful ever held by this Society. Twelve technical sessions of outstanding value were arranged by the Meetings Committee, and the response of the membership in general gave ample evidence of the acceptability of the material provided and the manner of its presentation.

The Carnival offered the chief social attraction of Annual Meeting week, and was attended by over 1000 members and guests, who reported almost without exception that their fondest expectations had been amply fulfilled.

A majority of the technical papers that were presented at the Annual Meeting are printed on the following pages; others will follow in subsequent issues of THE JOURNAL. An illustrated news account of the meeting will also be found in this issue, beginning on p. 81.

Society Meetings for the Year

DURING the present administrative year, the Society will hold a Tractor Meeting in cooperation with the American Society of Agricultural Engineers, a Summer Meeting devoted largely to general engineering topics, a Production Meeting, an Aeronautic Meeting, a Transportation Meeting, an Annual Dinner and an Annual Meeting. The expressed intention of the Meetings Committee is to make these events of even greater interest and value than those that have been held during the past administrative year.

It has been felt that the matter of maintenance of automotive equipment has reached a position of prominence that warrants its inclusion in the program of the Transportation Meeting. This practice will be followed this year.

Tractor Meeting in March

COOPERATING again with the American Society of Agricultural Engineers, the Society will hold its annual Tractor Meeting in Chicago, March 25 and 26, the events of the first day being under the auspices of the Society of Automotive Engineers and those of the second day being handled by the American Society of Agricultural Engineers.

Tractor engineering and production papers will be presented at the morning session on the 25th, and topics pertaining to the application and operation of tractors will occupy the afternoon session. It is planned to provide a number of features in addition to the technical sessions that will most certainly attract a large number of engineers and production men who are interested in the current problems of the tractor industry.

Additional information concerning this National Meeting will appear in the March issue of THE JOURNAL.

Concerning Cumulative Indices

THE question has occasionally been asked, "Does the Society publish a cumulative index of its publications, covering their contents for all years, in addition to the index provided for each volume?" An index of this kind is not published, but information such as would be

obtained from it is readily available through the Research Department. In this department each article that has appeared in either THE JOURNAL or the *Bulletin*, which preceded THE JOURNAL, is indexed in a card file under the name of the author and main subject of the article, as well as under subsidiary or related topics. If the article is reprinted in the TRANSACTIONS, an entry is made on the cards giving exact reference to this second publication.

Should any member of the Society want a list of all the papers by a given author that have been published by the Society, or of all the papers on any given subject contained in its publications, a request to the Research Department will bring the information. Through this department also can be obtained such back-numbers of the Society's publications as are available, or photostats of requested articles when the supply of originals has been exhausted.

A card index, by authors and subjects, is kept also of papers that have appeared in other technical magazines, about 75 different publications being perused regularly for this purpose.

Educational Value of Meetings

A STRIKING feature of the sessions of the Society held in Detroit last month was their marked educational value. Information was given on several important new subjects, and able summaries, with deductions, were presented on matters that have been under discussion for some time. Among the new things were the Loening amphibian airplane, the Upson Metalclad rigid airship, the Attendu heavy-oil engine, the headlight out-of-focus data submitted by Porter and Prideaux, the head-lamp light-distribution data discussed by Ryan, the fuel-test information presented by James, and the non-diluting crankcase-oil described by Wilson. Among the summarizations were the papers on fuel detonation by Delbridge and Hill, on vapor-cooling by Taub and Saunders and by Herreshoff, on engine lubrication by Coleman and Fisher, on brakes by Allen and by Stanley, on superchargers by Short, by Iseler and by Moss, on refrigerated test-chambers by Pierson, and on engine starting tests by Eisinger. Exhibits relating to the principles involved and representing physical embodiments of the points of design presented were at hand in nearly all instances. Obviously, the best progress can be made by contact with the masterly development engineers who are assiduously engaged on the solution of major problems of the industry. Not least of the advantages of this fine meeting of the Society was the use of the excellent quarters of the General Motors Building, very generously provided, and including, in addition to the main meeting-rooms, restaurant and committee-sessions facilities.

The Cooperative Fuel-Research

AS was emphasized at the Research Session of the Society in Detroit last month, the cooperative fuel-research work that has been fostered for several years by the National Automobile Chamber of Commerce, the American Petroleum Institute and the Society, and conducted by the Bureau of Standards and the automobile industry in general, has resulted in great benefits. Through it the automotive engineers have gained a much better insight into the fundamental possibilities, and the engineers of the oil industry have become more thoroughly informed on the characteristics of conventional gasoline engines. Past-President Crane stated that the work has increased the available supply of motor fuel upward of 20 per cent, and helped to maintain satisfactory gasoline prices.

The original endeavor in the research was to increase the quantity of satisfactory gasoline available from a barrel of crude oil; this involving the determining of how heavy a fuel could be used satisfactorily. Then an investigation was begun in the matter of conditions that must be met in engine starting; this in turn involving how much of the right kind of fuel is available in cold weather, cold-starting depending on lower-end and not average volatility. The object of this research is to enable the oil companies to blend the fuels most effectively for use in cold weather. It should result in increasing very materially the quantity of suitable gasoline available in cold weather.

As stated at the meeting by T. S. Sligh, Jr., of the Bureau of Standards, the methods that have been especially devised in this investigation give a very definite idea of the starting value of a given motor fuel, and also of the distinctive volatility of a fuel as a whole, at say the 85 or 90-per cent point. This indicates the scope of the studies and the far-reaching effects that it is expected will be secured from the research as it proceeds.

PATENTS AND TRADE MARKS

RELIEF from former onerous conditions affecting American patent rights in foreign countries resulted from the International Convention for the Protection of Industrial Property, held at The Hague recently, according to the official report by Commissioner of Patents Thomas E. Robertson, who attended as chairman of the American Delegation. Practical elimination of the risk of forfeiture of a patent for non-working or for non-payment of taxes through accidental causes is described by the Patent Commissioner as a change of outstanding importance in the revised convention signed by every one of the 32 countries that were represented.

An agreement was reached that the period of 3 years, which must be allowed before any penalty can be imposed for non-working, is to be reckoned from the date of the grant of the patent instead of the filing of the application. Another important development is the provision as to the cancellation of fraudulently registered trade-marks, furnishing "an effective remedy against piracy of well-known trade-marks." Also the amendments with relation to unfair competition will be of benefit, especially in those countries that have not developed, as have the United States and Great Britain, a well-defined system of jurisprudence with respect to unfair competition. The adoption of the present convention represents a long step forward in the direction of doing away entirely with requirements of working in order to maintain a patent in force and diminishes the risk of a patentee losing his rights as in former years.

STANDARDIZATION ACTIVITIES

The work of the Divisions and Subdivisions of the S. A. E. Standards Committee and other standards activities are reviewed herein

PRODUCTION DIVISION HOLDS MEETING

New Group in Standards Committee Begins Production Standardization

The first meeting of members of the newly established Production Division of the Standards Committee was held in Detroit on Jan. 29 during the Society's Annual Meeting. The extension of the standardization activities into the production field of the automotive industries is the result of several months of consideration and preparation by the Society and consultation with the active production men of a number of the larger car and motor-truck builders and others who have been interested in establishing this Division. The possibilities of accomplishing a great amount of valuable work in automotive production, both directly and in conjunction with similar activities in the machine-tool and other related industries, are fully appreciated but as the work covers a field in which conditions, requirements and personnel are vastly different from those of the engineering branches to which the Society's standardization work has been largely confined, the policy of making a modest start has been adopted. Several subjects suggested from various sources were considered but for the time being the Division will take up only that of grinding which is a general but important one. Immediate results should not be expected in this work, however, as experience must be gained in organization, procedure and scope. Although many of the general principles that apply in engineering standardization apply in a measure to production standardization, the latter must be developed to meet its own peculiar conditions and requirements. The Division is also planning to cooperate actively with the Sections of the Society in the selection of production topics for Section meetings and their presentation and discussion to secure as wide-spread consideration of data as possible and to broadcast information regarding the Division and its work for the benefit of the industry at large.

The Division has been organized on the group plan, the groups including the Chicago-Milwaukee, the Detroit, the Cleveland and the Eastern districts. Each group will function very much as a Subdivision with its own chairman and in cooperation with the other groups. The following have accepted appointment on the Division and others will be added to round out a sufficiently representative personnel as the work requires: W. G. Careins, of the Ajax Motors Co., chairman of the Division and the Chicago-Milwaukee group; George Babcock, of Dodge Bros., Division vice-chairman and chairman of the Detroit group; G. E. Bechtel, of the White Motor Co., chairman of the Cleveland group; Eugene Bouton, of the Chandler Motor Car Co.; R. R. Keith, of the International Harvester Co.; LeRoy F. Maurer, of the Studebaker Corporation of America; E. N. Sawyer, of the Rollin Motor Co.; and James Thiel, of the Waukesha Motor Co.

SHEET-STEEL STANDARDIZATION

A meeting of the Subdivision on Sheet Steel was held on the afternoon of Jan. 28 during the Annual Meeting in Detroit, those present being W. C. Peterson, of the Fredericksen Co., chairman; E. F. Collins, of the Packard Motor Car Co.; J. W. Culp and R. B. Saylor, of the American Sheet & Tin Plate Co.; F. P. Pleasanton, of the J. W. Murray Mfg. Co., E. W. Upham, of the Chrysler Corporation; J. W. Watson, of the Hupp Motor Car Co. and C. E. Heywood, of the Society's Standards Department.

During the last several months information had been obtained at the direction of the Subdivision as to the sheet steel used by the different automotive plants and the tests followed in determining the suitability of the steel. As it was felt that the information obtained should be carefully summarized and submitted to the entire Subdivision, a Subcommittee, consisting of L. A. Danse and W. C. Peterson, was appointed to review the information.

Owing to changes in company connections of some of the Subdivision members, the Subdivision was reappointed by Chairman Watson, the new personnel being as follows:

W. C. Peterson, *Chairman*	Fredericksen Co.
W. E. Cougherty	Allegheny Steel Co.
L. A. Danse	Cadillac Motor Car Co.
J. M. Darke	General Electric Co.
C. N. Dawe	Studebaker Corporation of America
F. G. Elder	American Steel & Wire Co.
W. A. Irvin	American Sheet & Tin Plate Co.
G. L. Kelly	Edw. G. Budd Mfg. Co.
J. H. Nead	American Rolling Mills
E. W. Upham	Chrysler Corporation
F. E. McCleary	Dodge Bros.

Messrs. Cougherty, Dawe and Kelly are continued as representatives of the American Society for Testing Materials Subcommittee on Sheet Steel.

HEAD-LAMP CONSTRUCTION OUTLINED

Lighting Subdivision Recommends Desirable Head-Lamp Construction Details

Nine definite features of desirable head-lamp construction were determined upon at a meeting of the Lighting Division Subdivision on Head-Lamp Construction held on Jan. 28 during the Annual Meeting in Detroit. The definite points determined upon follow:

The fenders should not be tied together through the head-lamps.

The construction should be such as to permit the installation of the lens in the proper position only.

The construction should be such that the lens is securely held while the door is being removed.

The construction should be such as to protect the lens against excessive local strains.

Suitable provision should be made for the drainage of moisture condensing in the head-lamps.

The design relation between the socket and the reflector should be correct when the door is installed.

The finished reflector should withstand corrosion under normal service conditions.

The reflector should be of such design and weight as to show no beam distortion when assembled in the head-lamp.

The cross-sectional area of the beam at 100 ft. shall come within a circle having a diameter of 126 in.

These points were based on suggestions submitted by A. W. Devine, engineer in charge of the equipment section of the Massachusetts Registry of Motor Vehicles. The Subdivision will develop a test specification for determining the rigidity

of head-lamps and will submit it to all head-lamp manufacturers with the request that the test be used on all head-lamps in regular production. If the data obtained do not indicate that the test is satisfactory, the expectation is that the test data available will make it possible to develop a satisfactory specification. The Subdivision will also make actual tests to determine proper specifications for corrosion and the durability of the finish on reflectors under normal service conditions.

Those present at the morning session of the Subdivision were R. N. Falge, of the National Lamp Works of the General Electric Co., chairman; G. P. Berry, of the General Motors Corporation Research Laboratories; H. S. Broadbent, of the Westinghouse Lamp Co.; W. B. Churcher, of the White Motor Co.; Harry Doane, of the Buick Motor Co.; G. P. Doll, of the Thomas J. Corcoran Lamp Co.; C. A. Michel, of the Guide Motor Lamp Mfg. Co.; H. H. Oetjen, of the Edmunds & Jones Corporation; L. C. Porter, of the Edison Lamp Works of the General Electric Co.; B. M. Smarr, of the General Motors Corporation; Herman Schwarze, of the Oakland Motor Co.; G. H. Stickney, of the Edison Lamp Works of the General Electric Co.; T. Earl Wagar, of the Studebaker Corporation of America; and C. E. Heywood, of the Society's Standards Department. Following the Headlighting Symposium on that afternoon, the Subdivision met again, those present being H. S. Broadbent, B. M. Smarr, Harry Doane, G. P. Doll, R. N. Falge, J. H. Hunt, C. A. Michel and C. E. Heywood.

COOPERATIVE TESTS TO BE MADE

Subdivision on Physical-Property Charts To Verify "Frequency" Curves

Since the March, 1925, meeting of the Iron and Steel Division, the Subdivision on Physical-Property Charts has obtained test data covering S.A.E. Steels which are to be used as a basis for developing revised physical-property charts, using the following formula

$$X = [(P/p) - 1]\,(t/T)^n + 1$$

where

n = a factor indicative of the quality of the steel

P and p = ultimate tensile-strengths

T and t = temperatures

This formula permits the construction of a curve for the ultimate strength of any steel providing two points on the curve are known. The decision to develop these revised charts based on frequency curves was made by the Division after it was generally agreed that the charts now printed in the S.A.E. Handbook indicate the worst possible conditions only, whereas charts based on frequency curves indicate the values most likely to obtain.

It was decided at the Subdivision meeting, held in the General Motors Building during the week of the Annual Meeting, to restrict the work of the Subdivision to S.A.E. Steel No. 6130 and to conduct a series of cooperative tests on 100 test-specimens of this steel to verify definitely the accuracy of the frequency curve for this steel based on the existing data.

Twenty-two laboratories are to be asked to participate in the cooperative tests. The steel will be furnished by four steel companies and test-specimens will be made by Chairman Watson and distributed to the collaborators. The heat-treatment to be used will be to heat to 1575 deg. fahr.; to hold until uniform; to quench in water; and to draw at 800, 1000 or 1200 deg. fahr. for 1 hr. The results of these tests will be keyed before they are released so that the actual results of any one laboratory cannot be compared with the results obtained by another.

Those present at the Division meeting were J. M. Watson, of the Hupp Motor Car Corporation, chairman; Robert Atkinson of the Halcomb Steel Co.; A. L. Boegehold, of the General Motors Corporation Research Laboratories; J. D. Cutter, of the Climax-Molybdenum Co.; J. B. Dailey, of the Chrysler Motor Car Co.; C. N. Dawe, of the Studebaker Corporation of America; R. J. Giblin, of the Buick Motor Co.; E. J. Janitzky, of the Illinois Steel Co.; W. C. Peterson, of the Fredericksen Co.; A. P. Spooner, of the Bethlehem Steel Co.; T. H. Wickenden, of the International Nickel Co. and C. E. Heywood, of the Society's Standards Department.

TWO-FILAMENT CONNECTOR ENDORSED

Special Construction Adopted To Ensure Proper Connection of Plug and Socket

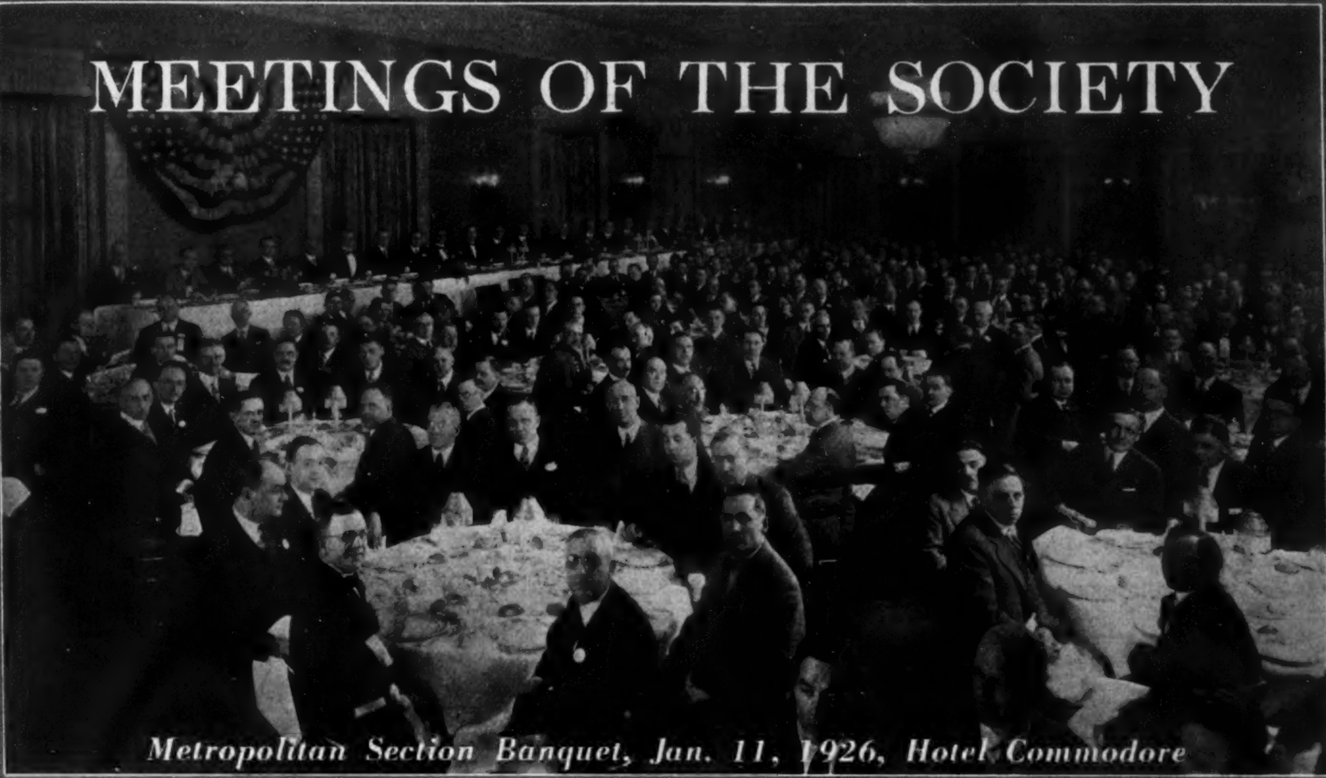
As a result of the adoption of two-filament lamps by several of the car builders, putting the plug and socket of the connectors together with the correct contacts interchanged makes possible the lighting of the lower head-lamp filament when it is desired to light the upper filament or vice-versa unless the connectors are designed so that the plugs and sockets can be put together in the correct way only.

The connectors now used by the Studebaker Corporation of America, the Hupp Motor Car Corporation and the Buick Motor Co. have dimensions agreeing with the present S.A.E. Standard double-contact connector as printed on p. B5a of the S.A.E. Handbook with the exception that one pin is offset 15 deg. from the vertical center-line. With this type of connector, one contact can be used for either the auxiliary filament in the head-lamp or for the tail-lamp filament and the other can be used for the main filament in the head-lamp or for the stop-lamp filament.

At the meeting of the Subdivision on Bases, Sockets and Connectors, which was held in the General Motors Building on the afternoon of Jan. 27 during the Annual Meeting, it was suggested by C. E. Godley that an alternate S.A.E. Standard for two-filament lamp connectors should be adopted to avoid the development of several different designs of this type of connector. As it was felt that such standardization should follow current practice, the 15-deg. pin offset was approved by the Subdivision.

Those present at the Subdivision meeting were C. E. Godley, of the Edmunds & Jones Corporation, chairman; G. P. Berry, of the General Motors Corporation Research Laboratories; C. C. Bohner and D. A. Harper, of the Tung-Sol Lamp Works; H. S. Broadbent, of the Westinghouse Lamp Co.; C. H. Culver, of the Culver-Stearns Co.; G. G. Meade, of the Chicago Electric Mfg. Co.; A. J. Scaife, of the White Motor Car Co.; and C. E. Heywood, of the Society's Standards Department.

MEETINGS OF THE SOCIETY



Metropolitan Section Banquet, Jan. 11, 1926, Hotel Commodore

NEW DEVELOPMENTS AT THE SHOW

Engineers of Exhibiting Companies Give Brief Talks before Metropolitan Section

What Is New at the Automobile Show was the subject of the meeting of the Metropolitan Section that was held on the evening of Jan. 11, the Monday following the opening of the New York show. The excellent plan was followed of having the engineers from the exhibiting car companies tell in 5-min. talks the improvements made in the new models of their cars, with the idea that these talks would present an advance survey of the new features of the latest models and indicate to those attending the meeting what to look for and where to find it.

The meeting was held in the east ballroom of the Commodore Hotel and was preceded by a dinner at which members of the Section and their guests renewed old acquaintances and formed new ones among out-of-town members of the Society. Among the guests were several from England who had come to New York City as delegates to the World Motor Transport Conference organized by the National Automobile Chamber of Commerce. These were H. G. Burford, past-president of the Institution of Automobile Engineers; Frank Lanchester, of the Society of Motor Manufacturers & Traders; R. D. Winn, of the Motor Traders Association; and Major Seawright, who has done considerable research work on carburetion in England. The visitors were called upon by Chairman Neil MacCoull to address the meeting.

Mr. Burford spoke of the great world brotherhood of automotive engineers imbued with the ambitions and ideals of service and said that one of the objects for which the Institution of Automobile Engineers is striving is to educate and raise the status of the engineer in England. Mr. Lanchester paid a tribute to the engineering ability of this Country, which entered the automobile field after the European countries and has attained amazing results.

The full story of the Annual Meeting begins on p. 81

Auburn and Buick Improvements

Speaking of the Auburn car, J. M. Crawford, chief engineer, said that, in an endeavor to correct tramping, the side-rails of the frame have been increased to 7/32-in. thickness, 6-in. depth and 2½-in. flange. A tubular cross-member has been put in just back of the transmission in the open models. Wheels have been reduced 8 lb. in weight by lightening the rims and felloe bands. Adoption of the four-plane suspension system did more, he said, to solve the problem than anything else. Greater power has been secured from the eight-in-line engine by increasing the bore ⅛ in. and the axle ratio was decreased to 4.63 to 1.00, resulting in a smoother-running car at speeds of 45 m.p.h. and more. Spark control is hooked up with the ignition switch.

This year's changes in the Buick line, according to E. A. DeWaters, chief engineer, consist in increasing the power-plant output about 16 per cent, the addition of air-cleaners, oil filters and gasoline strainers. Dust shields have been fitted to the drums of the external four-wheel brakes. The turning radius has been decreased and the steering-gear in the larger cars increased in size so that the cars steer more easily. The new models are equipped with tilting head-lamps to depress the beam when approaching other drivers.

Cadillac and Cleveland Refinements

Six lantern slides of improvements in the Cadillac were shown and commented upon by W. R. Strickland, assistant chief engineer. These included the new radiator of improved design that has a built-in shutter to keep the engine warmer in winter and to warm-up the lubricating oil more quickly; a crankcase ventilating system to remove moisture from the oil; reduction of the crankshaft weight by about 30 lb.; the use of one instead of two water-pumps and a simpler and more accessible oil-pump; simplification and reduction in weight of the starting motor, distributor and cylinder blocks; more compact combustion chamber; and more flexible springs, with semi-elliptic rear springs without platform spring and with ball shackles, which give the simplicity of the semi-elliptic spring and the flexibility of the platform spring.

Cubic capacity of the Cleveland engine has been increased approximately 8 per cent by an increase of 1/8 in. in the bore, and improved performance under all conditions has been secured by placing the intake header above the intake ports and exhaust-jacketing the steel-tube riser from the carbureter, said Balfour Read, chief engineer. Transmission shafts have been enlarged and the countershaft-bushing lubrication improved by grooving the bushings. Ribbing of the rear-axle carrier has been altered to give better support for the side bearings and reduce distortion under load. Modifications have also been made in the rear springs and their hangers, and a steering-gear having a hollow worm and two-tooth sector with a ratio of 12 to 1 has been adopted and is readily adjustable for back-lash.

Both the Flint Big Six and Light Six have lock-tooth three-shoe internal brakes, said Joseph Rawley, assistant chief engineer, and the engine of the Light Six has been increased from 196 to 236 cu. in. piston displacement. A gasoline strainer, air-cleaner, oil filter, semi-automatic ignition, and electric coincidental car-lock have been adopted.

Changes in Franklin and Lincoln

Radical change in appearance has been the chief modification in the Franklin, said Edward S. Marks, chief engineer. The frame has been lowered 3 in. It is still of wood but is dropped in the middle section to accommodate the new body lines. Steering-gear ratio has been increased to 8 to 1 and steering-knuckles and yokes have been made more rigid. A vibration absorber has been introduced in the engine fan. Copper cooling fins have been substituted for the steel flanges and the radiation surface increased about 1½ times. Compression pressure is now about 77 lb. and gives increased power without increased cylinder capacity. The starting and lighting system and the suspension springs have been changed, wheel hubs and spokes enlarged and larger tires adopted.

Extreme quietness of the Lincoln engine has been obtained by redesigning the valve-operating cams to seat the valves less abruptly, explained Thomas J. Litle, Jr., chief engineer. Open sport cars have been added to the line of body models, stainless steel is now used in several parts of the car where ordinary steel rusts, a new type of chain to resist wear and stretching has been adopted, and a new highly lustrous finish is applied over a nitrocellulose base. The head-lamps have a double-filament bulb and tilting reflector. All bodies are of aluminum, brake drums are ground after mounting on the wheels, springs have been made more flexible, and the rear springs are 60 in. long.

The New Locomobile and Rickenbacker

Probably the smallest straight-eight in the market has been added as a new model by Locomobile, according to Thomas L. Cowles, assistant chief engineer. The engine has a displacement of only 200 cu. in. and develops 65 hp. It drives the 124-in. wheelbase car 25 miles per gal. of fuel. Another new model is a large chassis for custom-built bodies and has the instrument panel mounted integrally with the chassis and all wiring complete with the chassis with a plug on the instrument board for plugging-in the body wiring. This car weighs about 1000 lb. less than the former Locomobile models.

Some of the major improvements on the Marmon, as mentioned by Stanley Zweibal, are strengthening of the frame, a new clutch with sets of springs between the plates, spring rear-engine support, double ignition with two plugs in each cylinder and a single distributor-head having 12 contact points, central chassis-lubrication, and an oil purifier developed in the company's own laboratory.

Four-point engine suspension has been adopted by Rickenbacker, said C. L. McCuen, because of the use of balloon tires. A speed model has been added to the line, the engine of this model having been altered to give more power by a change in the manifold that has improved the volumetric efficiency so that the engine develops 107 hp. and drives the car at 90 m.p.h. This model is fully streamlined underneath, which gives an increase of 5 or 6 m.p.h. at maximum speed.

Eight-Cylinder Stutz Built Lower

The new Stutz "safety" chassis, shown by numerous lantern slides, is built very low by hanging the worm drive under the axle, as explained by Charles S. Crawford, chief engineer. This permits of lowering the chassis appreciably more than is possible with the standard bevel-gear axle construction so that the floor is only 20 in. from the ground yet the clearance under the worm is ¼ in. greater than that under the bell-housing of one of the most successful makes of car in the Country. The frame has a double drop and the car's center of gravity is tremendously lowered. A cam-and-lever steering-gear with center ratio of 19 to 1 gives ease of steering. Automatic lubrication of the chassis is obtained by a magazine system replenished from the engine pump. The engine is a vertical straight-eight of the 2-4-2 type which is inherently balanced. The overhead camshaft is now driven by tandem silent chains with double automatic-adjustment idlers. Six-segment full-floating hydrostatic brakes make it possible, the speaker said, to bring the car to a full stop in 7 sec. from a speed of 70 m.p.h.

The Velie engine, transmission and bodies have been changed, said Herbert C. Snow, chief engineer of the company. Stroke of the pistons has been increased 3/8 in., thereby giving the engine 7 cu. in. more capacity. The crankshaft has been counterweighted and the valves made larger. The combustion-chamber is now entirely in the head. The transmission clutch-shaft and gears have been made larger. Twenty-in. road wheels have been adopted and the brake drums are ground on the wheels. A flexible attachment between the roof of the de luxe sedan body and the front pillars and sloping windshield allows the body to weave with the car frame without injury to the cowl.

The meeting was concluded by a talk by Donald Blanchard, technical editor of *Motor World Wholesale*, who showed many slides of photographs and sketches made at the show and gave a survey of the latest trend in engine, chassis and body design.

CHARACTERISTICS OF AUTOMOTIVE FUELS

New England Section Discusses Fuels Available and Methods of Utilization

Taking as his subject Present-Day Fuels and Better Methods of Utilizing Them, J. H. Shoemaker, distribution manager for the Swan Carburetor Co., Cleveland, presented a paper at the meeting of the New England Section held on Jan. 18 at the Engineers Club in Boston. During the course of his delivery of the paper, he enlarged upon important factors affecting fuel usage in internal-combustion engines, such as the breaking-up of the fuel, the distribution of the mixture and the elimination of pockets and of dead-spots in the manifold. In this connection, he brought out many interesting details regarding fuel characteristics and fuel usage, and these were supplemented by the other important information that developed as a result of the discussion that followed the presentation of the paper. Twenty-six members and guests attended the dinner that preceded the meeting, and 50 people were present at the meeting.

GEAR PUMP NOT DESIRABLE

Incorrect Statement Concerning Harrison Paper on Evaporative Cooling

In the news account of the Detroit Section meeting held on Dec. 17 at which Herbert Harrison presented a paper dealing with evaporative cooling an unfortunate error was made in connection with the statement of the general principles of this cooling method. In the third of these principles, which are given at the bottom of the second column on p. 7 of the January issue of THE JOURNAL, the omission of a prefix changed the entire meaning of the last line. This should have read "a gear pump is undesirable."

CONTROL OF HEADLIGHT EFFECTIVENESS

Washington Section Informed of Controllable Beams and Two-Filament Equipment


R. E. Carlson

Dividing his subject, Motor-Vehicle Headlighting, into (*a*) the operation, advantages and shortcomings of the present system; and (*b*) the development work in progress or proposed, from which it is hoped that an improved system will result, R. E. Carlson, of the Bureau of Standards, City of Washington, delivered the paper scheduled for the meeting of the Washington Section held on Jan. 8. He said that, on July 16, 1925, according to the report of the Illuminating Engineering Society's committee, approximately 54 per cent of the 16,077,165 motor cars registered in the United States and Canada were operated under State or other headlight laws based on the American Standard System, a system of regulation that contemplates the use on motor vehicles of approved devices only, approval being made by a State or other administrative officer and being founded on the results of laboratory and road tests. The specifications under which laboratory tests are made control, in a general way, the form of beam and set maximum and minimum requirements for beam candlepower that is consistent with safety.

Outlining the test-specification development-history, Mr. Carlson stated that, according to the specifications, any device passing the laboratory tests should, when properly adjusted and applied to a car, give a driving light adequate for most purposes and produce the minimum amount of glare on level roads; but, in practice, the direction in which the beam is thrown will not always correspond to that shown when testing head-lamps, due to the influence of springs and the effects of loading, since loading a car raises the head-lamp beams. For this reason, a compromise aim of beams is made so that, when the car is fully loaded, the top of the bright portion of the beam will not rise above the level of the head-lamp centers. This led to a survey from which loading allowances were determined and recommended for phaetons, sedans, coupes, and roadsters having wheelbases of from 100 to 140 in., although this made the vehicle less satisfactory for driving when empty, particularly if the wheelbase is short. Hence, a controllable-beam system was sought.

Following an analysis regarding the approval of headlight devices, Mr. Carlson remarked that the policy of approving only complete head-lamps is already showing results, as the lamps that have been tested lately by the Bureau of Standards for the District of Columbia and for the State of Oregon are of much better design and construction than was true formerly. Approval of the devices is only the first step, however, in Mr. Carlson's opinion, and the difficulties that attend the application of the present system constitute the main obstacle.

Controllable-Beam Equipment

Citing the headlighting situation now obtaining in the District of Columbia as an example and discussing it in considerable detail, Mr. Carlson averred that the application of the present system should go along concurrently with the research and development work necessary to produce something better. He then described controllable-beam equipment that enables the main beam from the head-lamp to be depressed at the will of the car operator, together with two-filament headlight beam-control, saying that the principle of depressible beams is being adopted widely and is a logical extension of the present system that should go far toward improving headlighting conditions.

In conclusion, Mr. Carlson discussed also the subject of diffused lighting, involving the use of frosted bulbs, and stated his belief that the steering committee, comprising representatives of the Society and of the Illuminating Engineering Society, will give added impetus to headlighting research and result in improvements of far-reaching importance.

CARBURETER ADJUSTMENT AND EFFECTS

Southern California Meeting Hears About Correct and Incorrect Adjustments

One hundred and twelve members and their guests sat down to dinner at the City Club in Los Angeles the night of Jan. 8 preceding the monthly meeting of the Southern California Section, which was one of the most largely attended meetings ever held by it. A musical program, arranged by Secretary Ethelbert Favary with the aid of the Artists' Club, was rendered during the dinner.

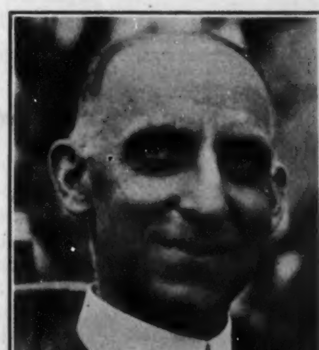
The subject of the meeting following the dinner was Carbureter Adjustment, and explanations of how to determine the correct adjustment and of the effects of improper adjustment on fuel economy, engine power and wear, carbon deposition, and crankcase oil-dilution were made by O. H. Ensign, of the Ensign Carburetor Co.; J. F. Dixon, of the Zenith Carburetor Co.; T. O. Duggan, of Chanslor & Lyon, agents for the Stromberg carbureter; and J. S. White, of the Wheeler-Schebler Carburetor Co.

A considerable number of members took part in the discussion and the meeting was interesting in every way.

The next meeting is to be held on Feb. 12 and the subject will be Engine Cooling, Radiators and Steam-Cooling. The speakers will be G. A. Dockeray, of the Eagle Radiator Co., and several others.

OBTAINING MAXIMUM MILES PER BARREL

Northern California Section Told About Efforts To Solve Fuel Problem


Dr. H. C. Dickinson

At the meeting of the Northern California Section, which was held in San Francisco on Jan. 22, Dr. H. C. Dickinson, of the Bureau of Standards, told the 98 members and guests who attended of the cooperative work being done by the American Petroleum Institute, the National Automobile Chamber of Commerce and the Society to bring about a standard for motor fuel, stating that a fuel shortage is approaching with a resultant increase in the price of gasoline. The speaker pointed out that the problem calling for solution was how to obtain, on a level road, the maximum number of miles per barrel of crude oil. Changing the end-point produces crankcase-oil dilution and hard starting, he said, and added that changes will have to be made in the cylinder-wall and crankcase temperatures.

Three grades of gasoline, aviation, commercial and benzol, are available. Dr. Dickinson advocated the use of a blend of gasoline from three different runs as such a blend would enable power output and ease of starting to be controlled. Spark setting and speed of ignition, in his opinion, also play an important part in engine operation.

The presentation of the paper was supplemented by numer-

ous lantern slides and a very elaborate set of experiments. Numerous charts giving a comparison of the time required for an engine to start at various temperatures with different grades of fuel were also shown.

Plans for February Meeting

The speaker at the February meeting will be W. S. James, who will have as his topic Gasoline and New Fuel Tests. Reports of the meeting of the American Petroleum Institute, which was held at Los Angeles, Jan. 19 to 22, and the Annual Meeting of the Society at Detroit, will be given. The meeting will be preceded by a dinner at the Engineers' Club at 6:30.

OPPORTUNITY AS AN ENGINEERING ASSET

Field for Automotive-Transportation Engineers Outlined to Buffalo Section

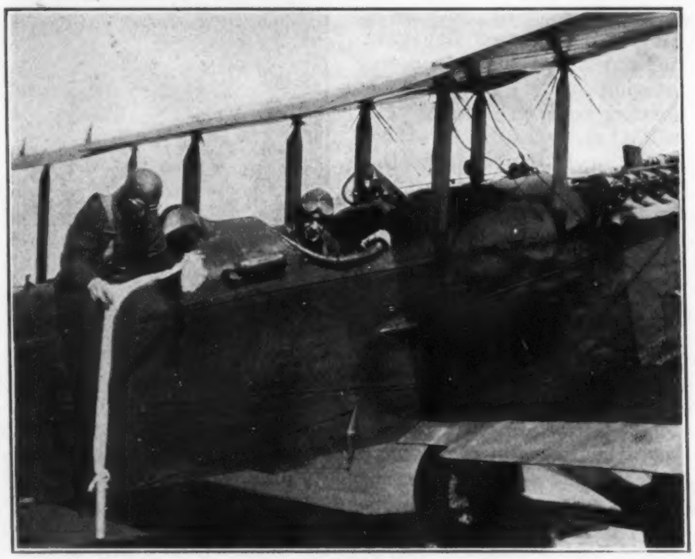
J. Edward Schipper

Problems relating to adequate and safe automotive transportation often are considered with too slight a realization of their importance, their complicacy and their amazingly rapid rate of increase in size and in number due to continued increases in the output of automotive vehicles of all sorts and in the demands for satisfactory transportation as a great public need. For these reasons, it is likely that many engineers of the automotive industry fail to appreciate wholly the opportunity these conditions present in providing a worthy field for their specialized endeavor, and it is stimulating to know that J. E. Schipper, Eastern representative of the Chilton-Class Journal Co., Philadelphia, chose Opportunity in Transportation for the Automotive Engineer as the subject of the paper he presented at the meeting of the Buffalo Section held on Jan. 19.

SPEEDY PHOTOGRAPHIC SERVICE

Latest Methods in Aerial Photography Described to the Dayton Section

Exhibits of photographic equipment and an address on the new science of taking photographs from supercharged airplanes at great altitude occupied the attention of the members and guests in attendance at the meeting of the Dayton Section held on Jan. 20. Lieut. George W. Goddard, chief of the aerial photographic branch of the Air Service, McCook Field, was the speaker and his paper on the subject evoked great interest. The only night photographs ever made up to this occasion were shown, and the methods by which aerial



Airplane with Special Equipment for Aerial Photography

Dr. S. M. Burka Is Seen Demonstrating the Message Tube in Which the Picture Is Dropped After Being Taken and Developed in 8 Min. While the Airplane Is in Flight. Lieutenant Goddard, Who Was the Speaker at the Dayton Section Meeting, Is in the Pilot's Cockpit. The First Aerial Flashlight Photograph Ever Made Was Taken from This Airplane on Nov. 20, 1925, While Flying over Rochester, N. Y., at a Height of 3000 Ft. A Flashlight Torpedo Containing 50 Lb. of Magnesium Powder Was Released from the Airplane and Furnished the Necessary Light for 1/20 Sec.

SCHEDULE OF SECTIONS MEETINGS

FEBRUARY

3—Milwaukee Section—Our Traffic Problem and the Future—A. W. Herrington
5—Washington Section—Storage Batteries—G. W. Vinal
9—Pennsylvania Section—Servicing Problems in Connection with Motorcoach Operation—A. E. Hutt
10—Dayton Section—Sleeve-Valve Engines—P. M. Heldt
11—Indiana Section—Oil Rectifiers and Crankcase Dilution—Ralph L. Skinner, William G. Wall and Joseph C. Coulombe
12—Southern California Section—Engine Cooling by Radiators and Steam Cooling-Systems—G. A. Dockeray and Paul Zering
15—Cleveland Section—Automobiles of Today and Tomorrow—Herbert Chase
16—New England Section—Production Meeting at Providence, R. I.
18—Metropolitan Section—The Outlook for Motorcoach Transportation in New York City—F. Van Z. Lane; Motorcoach Operation, Cities—Dean J. Locke; High-Speed Motorcoach Operation, Inter-City—Alexander Shapiro; Motorcoach Design and Construction—L. P. Kalb.
19—Chicago Section—Soothing the Internal Combustion Engine—Prof. Daniel Roesch
23—Buffalo Section—Progress in Airplane-Engine Design—Arthur Nutt
25—Detroit Section—Airplane Engine Maintenance—Lieut. Cyrus Bettis

MARCH

3—Milwaukee Section—Laboratory Methods and Technique—F. Jehle
11—Detroit Section—Speaker from the Bureau of Standards
Indiana Section—Motorcoach Development Meeting
15—Cleveland Section
25—Detroit Section—Production Meeting on Automobile Gearing

photographs are taken, developed and printed while in flight certainly constitute "service" that truly *is* "service." The meeting was preceded by a dinner at the Engineers Club.

THE INDUSTRY LOOKS TO THE ENGINEER

Kettering and Jordan, Horning and Lítle Address Nearly 1200 at Annual Dinner

C. F. Kettering, who was toastmaster at the Annual Dinner, held at Hotel Astor, New York City, on Jan. 14, 1926, said relative to continued advancement in industry that, until the engineers of the world have utilized every phenomenon of nature as nearly 100 per cent as the material will permit, our progress will go on. The statement came very fittingly at the end of an evening during which the chief matter under discussion was the extent to which engineers in the past have made use of phenomena of nature and the possibilities of still further utilization in the future.

W. L. Batt

Nearly 1200 Society members and guests attended the 1926 Annual Dinner. After a half-hour of social mingling in the reception rooms, the sound of a drum and two bagpipes was heard, and a trio of musicians in Scotch costume marched around through the crowd and led the way to the Ballroom which was the scene of the festivities. Immediately the lights were dimmed, and a spot-light was directed to a place at one side of the room where a banner suddenly was displayed, being let down from the balcony. This banner bore the name of one of the 13 Sections of the Society, together with a slogan appropriate to that Section. The spot-light traveled from place to place along the side of the room where in quick succession 12 other banners were unfurled, each one devoted to a local Section. Once more the spot-light moved, and a large banner came into view bearing the name of the Society, and an inscription telling about its 13 splendid Sections and its 5500 loyal members.

Throughout the dinner, music of several varieties was enjoyed. Maurice Garabrant, who had played on the organ during the half-hour of the reception, rendered more selections. The Wolfsie Orchestra played at intervals, and the Ritz Quartette sang. Frank Sherman, song leader, contributed to the crowd's enjoyment by his effective activity. An innovation was the showing of slides that portrayed cartoons of typical "barbershop" quartettes rendering old-time favorites; as the slides were shown, those present sang the songs indicated.

Horning Welcomes Members and Guests

When coffee had been served and cigars lighted, President Horning called for order, and a brief business session ensued, an account of which appears elsewhere in this issue of The Journal. At the close of the business session, President Horning welcomed the audience to what he termed the largest peace banquet ever held by the Society. He spoke particularly of the pleasure that the officers and members felt on this occasion because of the presence at the Dinner of a number of distinguished foreigners who were in this Country to represent their respective nations at the World Transport Congress.

After thanking the Society for the honor of the presidency and succinctly reviewing the progress of the last year in the various departments of the Society, President Horning turned the meeting over to Mr. Kettering, stating that it was one of the greatest pleasures of his administration to learn that Mr. Kettering, most loved and respected member of our industry, would serve as toastmaster at this Dinner.

Toastmaster Kettering responded in his gracious manner to President Horning and then delighted his hearers with a few serious, semi-serious and humorous remarks relative to the greatness of the automotive industry and its possibilities for growth, after which he introduced the Society's new President, T. J. Lítle, Jr.

Introduction of President-Elect Lítle

President-Elect Lítle felt that he expressed the sentiment of all the new officers when he said that they were greatly honored by being elected to office. Looking toward the future, he gave his view that the commercial supremacy of the industry depends largely upon the engineer, and expressed the belief that it is beneficial to the industry for young engineers to go into the plants and work their way up into executive positions. Stressing the importance of the production men and the need for greater cooperation between the engineering department and the production department of plants, he spoke of the desire of the Society to have production men participate further in its activities, and mentioned the Production Meetings of the Society and of the Detroit Section, where production men and engineers have the opportunity to get together and talk things over.

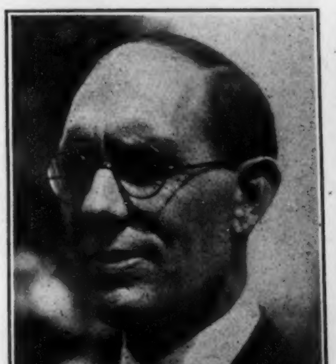
Relative to our product, Mr. Lítle felt that much yet remains to be accomplished in the improvement of the powerplant and hoped that the inventor and the engineer would get together for the purpose of achieving improvements, particularly in the matter of the conservation of the power developed by the engine.

In his introduction of the speaker of the evening, Toastmaster Kettering said that in the selection of the speaker the aim had been to get a man who represented as many of the factors of the automobile industry as possible. He characterized the speaker as an advertising man, an inventor, an engineer, a crusader, and a hero. In explanation he said that this gentleman had gone out and sold his wares in an audacious way and deserved the name of adventurer because of the fact that he is the only advertising man in the world who has ever attempted to make what he advertised. With these and other remarks in the same vein, the toastmaster introduced the principal speaker, Edward S. Jordan, president of the Jordan Motor Car Co.

Civilization Dependent on Low Transportation Costs

Mr. Jordan acknowledged the introduction by referring to Mr. Kettering as a distinguished inventor and an eminent experimental engineer; a man who would experiment with anything, even with public speaking.

Like Mr. Lítle, the speaker considered the engineer the dominant factor in the automotive industry. He said that Mr. Kettering did more to increase the sales of automobiles when he promulgated the self-starter than had practically all the salesmen in the industry put together; that the man who conceived and developed a set of tires that



C. F. Kettering

Edward S. Jordan

would travel 10,000 miles did more to increase the sales of motor cars than a host of advertising men. More than these and other individual contributions, said Mr. Jordan, was the work done by the Society in standardizing the production of motor-vehicle parts because no one can compute the saving thus made for the American public in the cost of transportation.

The most thrilling thing about this business, the speaker continued, is not in the selling and not in the advertising, but in the tremendous saving, the saving of hundreds of millions of dollars effected by the engineers and the production men of the industry. Mr. Jordan referred also to the tremendous contribution of the National Automobile Chamber of Commerce, working with the manufacturers and the engineers of the industry, and spoke especially of the incalculable saving brought about by the cross-licensing patent arrangement. Acknowledgment is due, he said, not only from the manufacturers whom the Chamber has directly served but from the public for its work in bringing about, in this business of providing transportation for the world at the lowest possible cost, a friendly cooperation that has never been equaled in any other industry. Appreciative mention was made also of the effect of the work done in the matter of securing good roads.

In the last analysis, said the speaker, the progress of every nation on the face of the earth, economically, politically, religiously, and culturally, depends upon the ton-mile cost of transportation; from ancient times until the present, the progress of the leading nations of the world has been in keeping with the progress in the reduction in cost per ton-mile. Just as rapidly as the cost per ton-mile is reduced and merchandise is delivered to its markets at a lower cost, the wage scale is increased, the standard of living is raised, and men are placed in a position to educate their children and to finance all religious and cultural interests. In the history of the world, those nations in which the rate per ton-mile is lower than in other nations have excelled in progress.

Because of these facts, said Mr. Jordan, the automotive industry is the greatest on earth. It is the fundamental of transportation and communication. The industry, he continued, is still in its pioneer days, and offers great opportunities to the young man just entering the field.

As a suggestion for a possible future development that would be of vital importance to the industry, to the nation and to the world, Mr. Jordan spoke of the need for the production of an aluminum alloy to be lighter, cheaper and better than steel and predicted that commercial domination, because of its close connection with the business of transportation, would depend upon the production of such a metal.

In conclusion, looking toward the future, Mr. Jordan said that no man in his wildest imagination can conceive of the progress of which the industry is capable, as no one has any idea of the extent of the demand for individual transportation.

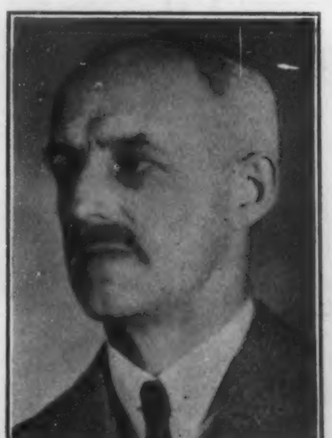
Toastmaster Kettering, expressing his pleasure at the speech just delivered, said that Mr. Jordan in discussing the question of the ton-mile rate had hit upon one of the very fundamental things of the world's progress. Mr. Kettering said further that the lowering of the cost per ton-mile is a result of converting natural resources into facilities, and that, as long as the human mind appreciates the value of this conversion of raw materials into facilities, nothing like the finish of engineering will be reached.

The Annual Dinner was under the capable guidance of Chairman W. L. Batt, who was ably assisted by the following Dinner and Reception Committee: Azel Ames, A. K. Brumbaugh, T. V. Buckwalter, J. R. Cautley, W. N. Davis, Earl G. Gunn, A. W. Herrington, W. E. Kemp, O. T. Kreusser, W. L. Moreland, F. E. Moskovics, C. L. Sheppy, E. P. Warner and E. C. Wood.

T. J. LITLE, JR., ELECTED PRESIDENT

At the 1926 Dinner that was held at the Hotel Astor, New York City, on Jan. 14, the result of the election of officers to serve during this administrative year that began at the close of the Annual Meeting of the Society in Detroit last month was announced. Charles E. Heywood, W. E. Kemp and H. M. Rugg, who constituted the tellers of election, reported that 958 ballots had been cast, only 1 of which was void. The result of the election with a few scattering votes was as follows:

President	
T. J. Litle, Jr.	953
First Vice-President	
J. H. Hunt	955
Second Vice-President Representing Motor-Car Engineering	
George W. Smith	958
Second Vice-President Representing Tractor Engineering	
O. W. Sjogren	958
Second Vice-President Representing Aeronautic Engineering	
Arthur Nutt	958
Second Vice-President Representing Marine Engineering	
George F. Crouch	957
Second Vice-President Representing Stationary Internal-Combustion Engineering	
C. O. Guernsey	958
Members of the Council	
Taliaferro Milton	958
J. F. Winchester	958
F. F. Chandler	957
Treasurer	
C. B. Whittelsey	958


Azel Ames


T. V. Buckwalter


J. R. Cautley


W. N. Davis

FOUR OF THE MEMBERS OF THE DINNER AND RECEPTION COMMITTEE

The Constitution of the Society provides that in addition to the officers elected at any Annual Meeting the President and the three Councilors elected at the Annual Meeting of the previous year shall be members of the Council. In accordance with that provision the following members of the 1925 Council will serve as members of the Council for this administrative year: Past-President Horning and Councilors Burkhardt, Foster and Warner. The Council is constituted of 15 voting members. Their photographs and sketches of their lives will be found on p. 139.

THE ANNUAL MEETING

A Complete News Account of This Important Gathering

ANNUAL MEETING SETS NEW RECORD

Over 900 Participate in Sessions; Demonstrations and Exhibits Evoke Enthusiasm

Judging by the comments of many of the Society's "old timers," the Annual Meeting in Detroit, on Jan. 26 to 29, can be recorded as perhaps the most successful national meeting ever held by the Society. As regards attendance, the registration totaled well over 900, whereas the total attendance at 12 technical sessions approached the 2500 mark. This has seldom, if ever, been equaled. The percentage of Society members as contrasted with guests was unusually high this year, and that the various events of the meeting made a very strong appeal to those who are vitally concerned with the engineering and production activities that are closely associated with current automotive engineering developments was readily apparent.

Among noteworthy features of the 1926 Annual Meeting were the extremely interesting and instructive exhibits and demonstrations that accompanied a great majority of the papers. Several of the demonstrations were very complicated as regards construction and manipulation of apparatus, and great credit should be given those in charge that the demonstrations were entirely successful.

The subject matter covered by the technical sessions was sufficiently diversified to fulfill the desires of specialists in many branches of the industry. The material, however, was so chosen by the Meetings Committee as to make a strong appeal to all progressive automotive engineers. The consistently large gatherings provided an unmistakable indication that the Committee's selection of topics, speakers and chairmen was altogether acceptable.

A number of novel features were incorporated in the so-called mechanics of the meeting, among them being the public address system that rendered the remarks of all speakers readily audible in all parts of the assembly room.

In an attempt to provide Society members promptly with a complete and accurate news account of the Annual Meeting, special arrangements were made whereby well-trained reporters attended the sessions and immediately prepared the accounts that were transmitted to the New York City office and to the printer with utmost dispatch. For example, a report of each morning's session was in type in New York City on the morning of the following day. To assure the accuracy of these reports, each staff reporter was provided with immediate copy by stenotype operators who attended each session.

With a view of presenting in as acceptable a manner as possible the news story that will be found in the following pages, an extensive series of photographs taken by N. Lazarnick has been provided to lend additional atmosphere to the material.

A number of the technical papers are presented in full in this issue of The Journal; others will follow in subsequent issues.

AUTOMOBILE-ENGINE SUPERCHARGING

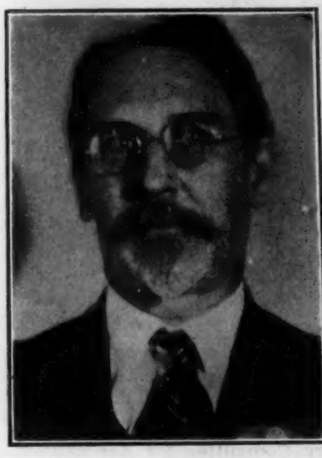
Supercharger History, Status and Future Application Ably Presented

Proof that the 1926 Annual Meeting of the Society would eclipse former meetings was indicated clearly by the auspicious opening of the first session at 10:00 a. m. on Tuesday, Jan. 26, at the General Motors Building in Detroit. Nearly 300 members and guests were present and they evinced intense interest throughout the presentation of the mass of data that the speakers and those who discussed the subject of superchargers and supercharging had prepared. Racy accounts of personal experiences with supercharging equipment and many lantern-slide illustrations of supercharger development and practice intensified the interest and the appeal that the idea of supercharging ordinarily makes.

In his paper on Supercharging Internal-Combustion Engines, which was the first of the papers presented, C. R. Short, chief engineer of the mechanical engineering section


H. A. Huebotter


C. F. Taylor


Sanford A. Moss


Frederick S. Duesenberg

Four Who Were Prominent in the Discussion at the Supercharger Session

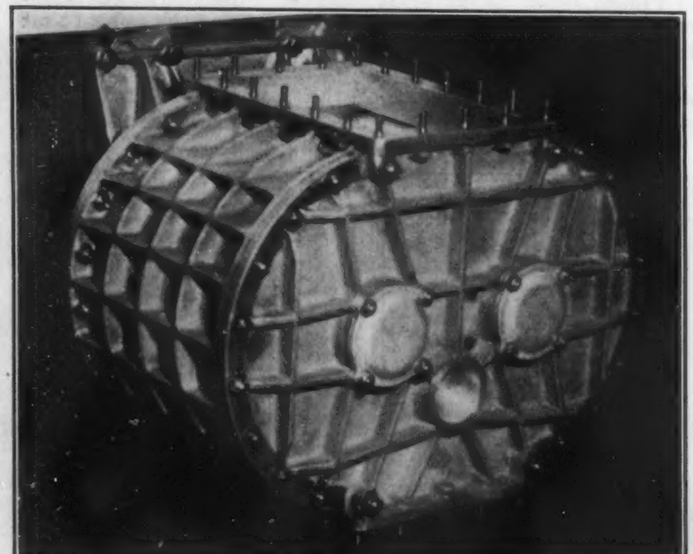
CHARLES R. SHORT

CHARLES W. ISELER

of the General Motors Corporation Research Laboratories, defined supercharging and gave a history of supercharger development to date. His paper is printed in full in this issue of THE JOURNAL, and reference is made thereto. The second paper, entitled Practical Application of Superchargers to Automobile Engines, was by C. W. Iseler, also of the General Motors Corporation. Mr. Iseler said in part that the Mercedes Company, in Germany, has on the market at present an automobile equipped with a supercharger of the Roots-blower type. The two models of this car thus equipped are respectively of 24 to 100 hp. and of 35 to 140 hp. The increased power, greater flexibility and higher speed obtained with this equipment in both Europe and America have shown the great possibilities attendant upon the adoption of the supercharger on passenger cars, he said.

SUPERCHARGER PROBLEMS ANALYZED

The paper deals briefly with the advantages that can be gained by use of the supercharger and presents an analysis of the problems involved. Citing, as an example, the results obtained with the Mercedes car, Mr. Iseler enumerated the advantages due to supercharging to be extra power, higher mechanical efficiency, greater flexibility, increased fuel-economy, and higher speed. Further, an engine can be built with the compression-ratio lower than the highest possible ratio from the viewpoint of prevention of detonation and yet obtain a surplus of power. The highest possible compression-ratio is determined by the tendency of the fuel mixture to detonate. The temperature at which detonation takes place is constant for each fuel and each mixture condition. The temperature of the mixture must, therefore, at all times remain below that causing detonation.



ROOTS BLOWER TYPE SUPERCHARGER
Constructed by the National Advisory Committee for Aeronautics and Exhibited at the Supercharger Session by Mr. Ware of Langley Field

Following a mathematical analysis of the mixture temperature upon entrance to the cylinder, for different compression-ratios without reaching detonation temperatures, Mr. Iseler went on to discuss the decrease in losses to the water-jacket, the possibility of opening the exhaust-valves later, the greater quietness obtained by a more gradual lift of the valves, the ability to use a smaller engine, the consequent decrease in the fuel consumption, and other points of advantage due to supercharging. He then presented numerous charts of curves showing comparative results obtained with and without supercharging as a preface to his presentation of detailed results obtained from the 24 to 100-hp. Mercedes car, which has a six-cylinder engine of 3.150-in. bore and 5.118-in. stroke. Its total displacement is 239 cu. in., its total car weight without passengers is 2800 lb., and the tire size is approximately 35 x 5 in.

The relation between the supercharged and the unsupercharged power-curves is approximately a straight line as to gain in output. The maximum gain is at maximum speed and is 54 per cent at that speed. In conclusion, Mr. Iseler said that no present supercharger enables the gearbox to be dispensed with as no supercharger can fulfil the conditions imposed on the gearbox for the added torque needed. No increase in engine torque at low speeds is expected in the Mercedes supercharger, and these cars are equipped with full transmissions. Mr. Iseler stated also that he expects the better class of cars will, in the next few years, be provided with supercharging equipment.

USE OF RATEAU PRINCIPLE

Following the presentation of the two foregoing papers, Chairman W. R. Strickland, of the Cadillac Motor Car Co., called upon Dr. S. A. Moss of the General Electric Co., to relate his experience with supercharger equipment. In complying with this request, Dr. Moss made his address even more vivid by exhibiting numerous lantern slides of varied types of supercharger. He said that the company he represents uses the Rateau principle of supercharging, but that many of the details of designs are those that already have been developed for the steam turbine. In regard to supercharging an airplane engine at great altitude, the object is to maintain as nearly as possible the conditions under which the engine operates at sea level; that is, to maintain at great altitude an inside engine pressure of 1 atmosphere at sea-level pressure, in the carbureter and in the intake-manifold, so that the engine will deliver full sea-level power. For example, a 400-hp. Liberty-12 engine at sea level might become, without supercharging, only a 200-hp. engine at great altitude, but an engine of large displacement might be made to deliver its full 400 hp. at great altitude if it were supercharged propery.

The centrifugal type of compressor is the one favored by the company represented by Dr. Moss, and he stated that the diffusor is a very important part. It changes high-velocity air at some pressure to slower velocity air at higher pressure, and great skill must be applied to its design. Efficiency curves obtained from good centrifugal compressors were exhibited, and the speaker said that recent results showed an efficiency of 70 per cent or more throughout the entire working range. Since all centrifugal compressors operate at high speed, they are geared.

Regarding Diesel engines, Dr. Moss remarked that the supercharged Diesel engine in Germany uses the centrifugal type of compressor. He believes that all Diesel engines will soon be supercharged. Supercharging has also been applied to a locomotive, and a picture of this was shown.

The barograph records obtained from the supercharged airplane engine flown by Major Schroeder in his memorable altitude-record flight following the war were shown and described, and among the other interesting information brought

forward by Dr. Moss was a chart showing the theoretical gain due to supercharging. Reverting to the Diesel engine he said that, in the two-cycle type, the determination of when scavenging leaves off and when supercharging begins is difficult. The supercharged Diesel engine has an improved combustion efficiency and the same effect is claimed for the supercharged gasoline engine. With supercharging, the increase in power for a given cylinder-volume over that attainable without supercharging equipment was stated as being from 30 to 50 per cent.

After the meeting was thrown open for general discussion, H. A. Huebotter, of Purdue University, mentioned that with the Roots-blower type of supercharger ordinary low-speed valve-timing can be used and still get good results at high speed. He stated that the centrifugal type of supercharging is done largely under constant conditions. In his opinion, any supercharging is unwarranted under variable-load operation. He said also that a supercharger interposed between the carbureter and the intake-valve gives good results at all speeds.

Supercharging Passenger-Car Engines

In outlining his experiences with supercharging equipment, F. S. Duesenberg, chief engineer of the Duesenberg Motors Co., Indianapolis, asserted that no automobile engine needs true supercharging. He thinks a better initial breaking-up of the fuel is needed most, so that the benefit of the increased efficiency thus attained will become effective at low speeds. He mentioned an experiment made in 1924 with a ¼-hp. motor capable of 12,000 to 15,000 r.p.m. that was used successfully to mix the fuel properly and believes such procedure more effective than the building-up of pressure. He thinks it necessary to suck air through the carbureter with a blower, and thus get a good fuel-mixture at all speeds. For this purpose a constant blower capable of operating at 12,000 r.p.m. is needed; that is, a constant-speed supercharger, regardless of engine speed, is needed for use on an automobile. In reply to a question from Mr. Duesenberg as to how the supercharger pressure builds-up, Dr. Moss answered that it does so in a geometric ratio.

C. F. Taylor, of the Massachusetts Institute of Technology, remarked that, in his opinion, to say that supercharging increases the engine power is better than to say that the efficiency is increased by supercharging. He referred to the noise made by a supercharger as being a serious objection to its application to a passenger car. At low speeds, an engine is working at the maximum pressure the fuel will withstand without knocking, and he questioned whether the pressure can be increased without increasing the knock.

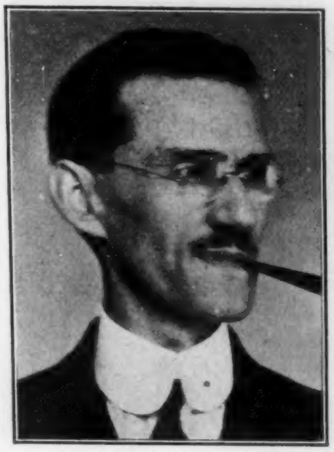
C. W. Smith, of Ohio State University, remarked that in an article which is to appear shortly in *Automotive Abstracts*, the statement will be made that in two-cycle engines using supercharging, the actual torque is greater at all times than when not supercharged.

Among other statements made supplementary to his paper, Mr. Short said that the mechanically operated valve can only be correct for one speed. He remarked also that the problem of supercharging is a very deep one and he thinks that ways must be devised to utilize supercharger principles to suit individual purposes and needs. He is sure that the supercharger is not limited to racing cars, and feels that a 20-per cent increase in efficiency can be attained all along the line by the use of supercharger equipment.

COLD-WEATHER OPERATION STUDIED

Laboratory Tests Car at –20 Deg. Fahr.; Fuel for Winter Starting Determined

Topics of seasonable interest were featured at the Research Session on Tuesday afternoon. Both papers, those of D. M. Pierson and J. O. Eisinger, dealt with investigations into the effect of low temperatures on automobile operation. Bringing into the session the actual tools of research, T. S. Sligh, Jr., demonstrated an apparatus that was being developed at the Bureau of Standards to measure the effective volatility of a motor-fuel. He showed how the results obtained with this checked with the results of Mr. Eisinger's engine tests.



T. S. Sligh, Jr.

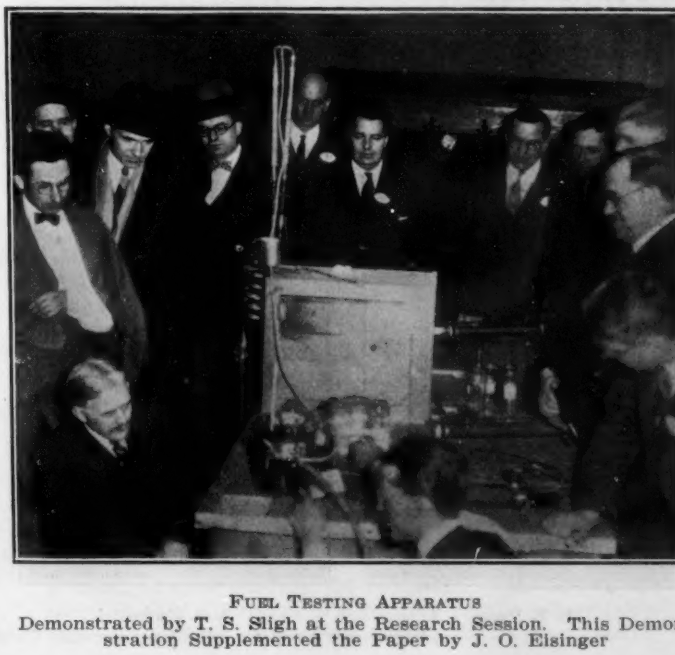
J. O. Eisinger

The Demonstrator (at the Left) at the Research Session and (at the Right) the Author of One of the Papers Presented

Chairman F. O. Clements, in introducing the subject of the session, referred to his long service of more than 26 years in the interests of research, and invited those interested to visit the General Motors Corporation Research Laboratory. He said that the motor-fuel question dealt with one of the most important classes of chemical reaction in the world, because this type of chemical reaction had brought into being the internal-combustion engine.

Low-Temperature Testing of Gas

In his address, An Improved Type of Refrigerated Test Chamber, Mr. Pierson touched on the extent to which research may be an adventure calling for exposure to discomfort, or even to danger. The chamber he described was designed to produce a temperature of —20 deg. fahr. To guard against exposure to such frigid conditions, workers are required to wear constantly a complete aviator's uniform. Further precautions described by Mr. Pierson consist of easy methods of communication between the cold chamber and the outer rooms, and automatic signals to bring help in case a worker is overcome. The cooling coils, to eliminate any possibility of disturbance to them and a consequent dangerous leakage of ammonia, in case of accident in the room, are mounted on a self-sustaining steel structure. Possible valve



Fuel Testing Apparatus
Demonstrated by T. S. Sligh at the Research Session. This Demonstration Supplemented the Paper by J. O. Eisinger

E. C. Newcomb H. W. Asire
AMONG THOSE PRESENT AT THE RESEARCH SESSION

leakage in the compressed-air line is also guarded against. Such a leakage would create an appreciable pressure in the room, with possible damage to the cork walls.

Two specific respects in which the cold room described overcomes difficulties presented by other installations of this type were mentioned by Mr. Pierson. One is the maintenance at all times of the transparency of the window through which an observer in a warm outside room can keep watch on the experiments in the refrigerated laboratory. Another is the prevention of the collection of moisture at the refrigerator doors. Lime in the plaster is held accountable for such dampness as due to its hygroscopic characteristics it attracts or absorbs moisture from the air. The use of cement plaster only, for inside and outside surfacing, is said to have given complete relief from this difficulty. Provision is also made for draining the water from the floor at two different points.

The sturdiness with which automobiles must be built can be gaged from the fact that the refrigerated laboratory is designed to test cars under conditions that prevail when they are running at from 35 to 40 m.p.h. in temperatures down to —20 deg. fahr. After giving a complete description of how these conditions are reproduced, Mr. Pierson pointed out that while the full possibilities of the room have not been tested, he assumes that its temperature, together with that of a 3000-lb. automobile, can be lowered from 70 to —20 deg. fahr, in 4 hr., and that a temperature of somewhat lower than —50 deg. fahr. can easily be obtained. Among the many problems to be studied, one particularly stressed is the positive determination of transmission power-losses from heavy lubricant in miles per gallon of gasoline, that have in the past been charged entirely to faulty carburetion.

A number of questions were asked following the presentation of the paper, in answer to which Mr. Pierson explained that the dynamometer controls can be operated only from the outside of the cold room; that, in making the tests, the engine crankcase oil is diluted to at least 10 per cent with kerosene to enable the starter supplied from the battery to function and that the radiator, which is left uncovered, contains an anti-freeze solution of alcohol which is varied in strength according to the temperature at which the tests are run. The maximum outlet-water temperature observed during the tests was given as about 110 deg. fahr., while the temperature of the lubricating oil in the circulating system was said to vary, during engine operation, from about —5 to about 105 deg. fahr.

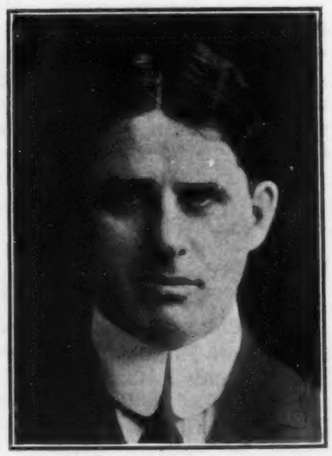
FUEL FOR COLD-WEATHER STARTING

In his paper J. O. Eisinger described the study of a particular cold-weather problem, the determination of what changes should be made in fuel volatility to produce the same starting characteristics in winter as in summer. In the tests covered in the report, fuels of differing distillation characteristics were used in a four-cylinder engine. The engine was driven by a dynamometer at a constant speed, until engine conditions had become reasonably constant, when fuel was turned on and the time required to obtain an audible explosion was taken. The total quantity of fuel as well as the time required to start the engine was measured, and both factors were determined for different rates of fuel flow from the carbureter jet. In presenting the results, these different mixture-ratios, since the engine speed was constant, were compared to the time required for starting. Curves were shown comparing different fuels under different conditions. Finally a comparison was made showing that one fuel under high-temperature conditions gives very nearly the same starting performance as another under low-temperature conditions. This was said to indicate the change in motor-fuel volatility that should be made from summer to winter to obtain the same starting characteristics in both seasons.

DEMONSTRATIONS SUPPLEMENT PAPER

The various devices described and demonstrated by Mr. Sligh were said to constitute the first steps in developing a method for making, in the laboratory, the tests for effective volatility that have already been made with the engine. Concurrently with this demonstration, Mr. Sligh gave, in a rough way, an illustration of the operation of the Engler distillation.

In the first experiment, suggested by Dr. H. C. Dickinson, a known quantity of gasoline and a small quantity of water were poured into a flask, the temperature of which was controlled. When the flask was shaken, the water caused a disturbance of the air and consequently the formation of a fuel-air vapor. A flame was applied to the mouth of the flask, to determine whether the air-fuel mixture, under the temperature conditions maintained, was explosive. Extensive experiments can be made with this simple apparatus, Mr. Sligh pointed out, to determine what fuel-air ratio, with any given gasoline at any given temperature, constitutes an ex-



R. S. Reed A. S. Russell P. L. Scott David Beecroft
FOUR OF THE OVER 900 MEMBERS AND GUESTS WHO ATTENDED THE ANNUAL MEETING




F. O. Clements
Research

Carl Breer
Brake

K. L. Herrmann
Body Production

W. R. Strickland
Supercharging

PRESIDING OFFICERS AT FOUR OF THE SESSIONS OF THE 1926 ANNUAL MEETING

plosive mixture and to fix the temperature at which a given fuel-air ratio of any gasoline will explode, in short, to discover the effective starting-volatility of a fuel.

Another device demonstrated, for obtaining the same results, consisted of two spirals into both of which air and fuel were fed at a constant and controlled rate under a constant and controlled temperature. Openings are provided for the outlet of the two streams of fuel-air vapor, and graduated tubes into which flow the streams of unevaporated fuels. In this set-up the quantities of fuel, of air and of condensate and the temperature of operation are all known. The ratio of the quantity of fuel supplied and that of the condensate is then a measure of the volatility of the fuel. The experimenter can also tell under what conditions an explosion is obtained from the fuel-air vapor escaping at the outlet.

The final apparatus shown by Mr. Sligh was an elaboration of the flask that was the first exhibit. This second flask was fitted with a stirrer to produce the air disturbance needed for the formation of the fuel-air vapor. An air-tight stopper, which blew off when the explosion was obtained, was also provided.

In the discussion of the cooperative fuel research, Mr. Eisinger brought out that tests on the starting-characteristics of fuels at temperatures about —10, and 0 deg. fahr. and at room temperatures were under contemplation. In the closing remarks, Mr. Clements and H. M. Crane both emphasized the value of the cooperative fuel research.

STANDARDS COMMITTEE MEETING

The 29 Division Reports printed in the January issue of THE JOURNAL, pp. 17 to 24, were adopted at the Standards Session on Tuesday afternoon as printed with the exception that the recommendation for piston and piston-ring oversizes was referred back to the Engine Division for reconsideration.


G. H. Adams C. M. Manly
IN ATTENDANCE AT THE STANDARDS COMMITTEE MEETING

Vice-Chairman Charles M. Manly presided in the absence of Chairman E. A. Johnston. After opening the meeting Mr. Manly introduced F. A. Whitten, appointed by President Lítle to serve as Chairman of the Standards Committee for 1926.

In connection with the committee action on the recommendation for piston and piston-ring oversizes, it was the consensus of opinion that it is not desirable to differentiate between oversizes for engines used in various industries, a single list of oversizes for all types of engine being preferable. It was also thought that some of the oversizes specified might be eliminated, the 0.003-in. piston oversize being mentioned as being more of a car builder's salvage oversize than a service oversize.

In presenting the report of the Ball and Roller Bearings Division, T. V. Buckwalter submitted a progress report on the standardization of roller bearings, copies of the roller-bearing dimensions proposed by the Subdivision, which consisted of Mr. Buckwalter, of the Timken Roller Bearing Co., and G. H. Adams, of the Bock Bearing Co., being given out at the meeting. This report is to be submitted to the Ball and Roller Bearing Division and will be printed in an early issue of THE JOURNAL.

THE BUSINESS SESSION

Effulgent and Stirring Address by President Horning on Current Conditions

The adjourned session of the 1926 Business Meeting of the Society, which had been convened at the Hotel Astor, New York City on Jan. 14, was held in Detroit on Jan. 26, with President Horning in the chair. Written reports of the Administrative Committees, of the Research and the Standards Committees, and of the Treasurer were distributed at the session. These reports were not presented separately but were summarized by President Horning in his address.

PRESIDENT HORNING'S ADDRESS

The address, substantially as delivered, was as follows:

During the year several financial problems of an important nature presented themselves. The most important fact in the financial set-up of the Society appears to be the cost of supporting the various activities of the Society that constitute the chief benefits of membership. This cost is about three times the amount of dues paid by the members. The manner of meeting this difference lies largely in the advertising revenue derived from THE JOURNAL. A very sound




FOUR SECTION OFFICERS WHO WERE AMONG THOSE PRESENT IN DETROIT
From Left to Right They Are L. M. Woolson, Vice-Chairman of the Detroit Section; F. F. Chandler, Vice-Chairman of the Indiana Section; F. G. Whittington, Secretary of the Chicago Section; and L. G. Meister, Secretary of the Dayton Section

and thorough editorial policy has resulted in an increasing number of pages of text, whose cost, while consistent with the character of THE JOURNAL, has to be constantly restricted. The number of interested readers among the executive class of members is increasing and THE JOURNAL is coming into its own among the better class of advertisers as a medium of the very highest value. The volume of advertising in THE JOURNAL depends on the prosperity of the industry and the constant efforts of the advertising department. The current revenue from advertising is running about $4,000 per quarter over the corresponding quarter of last year. This result is largely due to the efforts of Messrs. Robinson, Motz and Mills.

The strength of the Society lies in the manner and effectiveness with which important engineering information is disseminated. The care and effort taken in editing THE JOURNAL and the sound judgment used in keeping it at its high standard are greatly appreciated by those who have the opportunity to know of the constant vigilance exercised by General Manager Clarkson and the editorial staff.

H. L. HORNING AND T. J. LITLE, JR.
Discuss the Past, Present, and Future

The appropriation of the National Automobile Chamber of Commerce, together with the expenditure of the Society, for the purpose of standardization and research has been carefully administered and the Society points with great pride to its work of standardization as being its outstanding achievement, resulting in savings to the industry. Today a dollar buys more in the form of automobiles than of any other product, compared with the price levels of 1913. This has been accomplished by excellence in manufacturing methods, standardization and willingness to give the public the benefits of reductions in cost. The broad policy of the industry is reflected in the policy of the Society of giving more and more in service to its members as fast as its revenues permit.

In the last fiscal year the Society has operated on a budget and its net operating income has exceeded the net operating expense by $406.05, whereas the gross income exceeded the estimated budget income by $3,440.76.

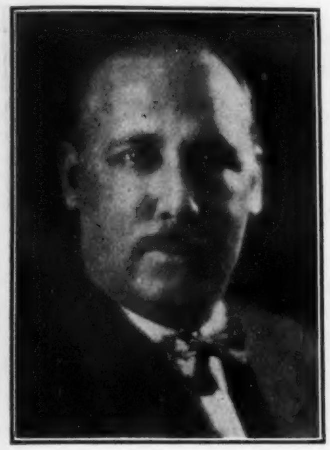
An effort has been made to improve accounting methods and safeguards have been adopted in investing the surplus funds of the Society in those securities that are legal for Connecticut Savings Banks. The services of the Investment Committee of the Chemical National Bank of New York have been used in choosing the securities for investment and sale.

MEETINGS MATTERS

Careful attention has been paid in the last year to the manner of conducting the major meetings of the Society. So successful has this effort been that more papers are now available on all important subjects than can possibly be handled in meetings or by the Publication Department. Attendance at meetings has exceeded all previous records. The technique of presentation has been greatly improved, moving pictures, models and actual mechanisms in operation now being shown whenever possible.

Nine major meetings of the Society have been held during the year as follows:

(1) Annual Dinner at New York City
(2) Annual Meeting at Detroit
(3) Summer Meeting at White Sulphur Springs
(4) Production Meeting at Cleveland
(5) Tractor Meeting at Chicago
(6) Automotive Transportation Meeting at Philadelphia
(7) Motorboat Meeting at New York City
(8) Aeronautic Meeting at New York City
(9) Service Engineering Meeting at Chicago




SOME "GENTLEMEN OF THE PRESS"
From Left to Right They Are Walter C. Boynton, *Automotive Daily News;* W. L. Carver, Chilton-Class Journal Co.; N. B. Pope, *Automobile Topics;* and R. E. Plimpton, *Bus Transportation*

The Meetings Committee started the year by laying down at once the schedule for the year and devoted itself throughout the year to guiding the home office in its efforts. The Council of the Society paid an unusual amount of attention to the meetings and particularly to the Annual New York City Banquet and these technical sessions. The manner of carrying out the desires of the Council reflects great credit on President-Elect Lítle, and on J. A. C. Warner, who has made a record for himself in his first year in this work. When it is realized that the home office conducts 9 major meetings per year and that the Sections hold 102 meetings each season, some idea of the work of the Meetings and Sections Department of the home office can be gained.

MEMBERSHIP

Under the able chairmanship of A. F. Masury, and the excellent work of Mr. Robinson of the home office, 725 new members qualified in the administrative year. During the year 480 ceased to be members for various reasons, conspicuous among these being relinquishing connection with the industry. The membership on Dec. 31, 1925, was 5419, plus 175 enrolled students, making a total of 5594. It is the belief of many that the membership can be increased 5 per cent annually for years to come.

It is obvious that there was fine cooperation among the members to produce a 14-per cent increase in new membership. Probably for every member more than one eligible potential member exists in the industry, outside the Society. Notwithstanding the high percentage of members who are shifting to other industries, the Society has a widening sphere of usefulness to the industry. Salesmanship is just as necessary here as in industry and the proper presentation of the activities and benefits of membership is essential.

STANDARDS

To review adequately the work of the Standards Committee is impossible. The wide scope of the subjects under consideration and the importance of each subject have brought about the policy this year of throwing overboard every project except those of pressing and outstanding importance to the industry. Great care has been exercised in keeping the committees as small and active as practicable.

The character and volume of the Standards work are such as to make the work of the Vice-Chairmen of the Standards Committee of increasing importance and, along with the Chairman, E. A. Johnston, I want to acknowledge the services of Charles M. Manly and C. C. Carlton, served as vice-chairmen.

During 1925, 200 subjects were considered, 113 existing standards being reviewed. Fifty-six standards were submitted at the Annual and Summer Meetings

VISITORS FROM THE OHIO STATE UNIVERSITY STUDENT GROUP
From Left to Right They Are T. H. Metzler, H. L. Cannell, John Younger, Who Is One of the Faculty Advisers, and F. L. Hirsch




S. Graves — Charles R. Harrman — William B. Barnes — E. S. Marks

SOME OF THOSE WHO ATTENDED THE ANNUAL MEETING

of the Society. Eighty-three subjects were before the Committee at the end of the year. Twenty-five Division Meetings and 12 Sub-Division Meetings were held. The Standards Committee consists of 29 Divisions and 53 Sub-Divisions, with 388 appointees to these committees.

The Society is cooperating with the American Engineering Standards Committee through seven Sectional Committees, of which four were established during the year, Society members being appointed thereto. The Society is represented on the Government Petroleum Specifications Board and on several Committees of the American Society for Testing Materials.

The most important change in the policy of the Society with respect to its standards is the publishing in the form of a revised book of the standards every 6 months, at no extra expense to the members. Great consideration was given to this matter by the Council and every phase of it was thoroughly examined before the new policy was adopted. The membership was canvassed and that this service to the members will be received with great appreciation appears certain. The book will be excellently bound and will open flat, being made of dictionary paper, thus reducing its thickness to that of a convenient size for coat pockets.

To carry out this plan, a limited amount of advertising will be carried in the S.A.E. HANDBOOK. The advertising will cover only products manufactured according to S.A.E. Standards and Recommended Practices and the text of the advertisements must be of a useful engineering nature for the members.

During the year the Standardization Policy Committee, under the able chairmanship of H. M. Crane, has met on various occasions for the purpose of defining the scope and nature of the standards work.

Let us pay tribute to the work and devotion to the service of the members of Robert S. Burnett and Charles E. Heywood, of the Standards Department. Only those who are privileged to come into contact with them and their work can appreciate adequately their fine character and efficiency.

RESEARCH

Administering the activities of the Research Department is one of the most important and difficult duties of the Society. As in our private researches, results do not always come as quickly as desired; yet the products are always fruitful, and frequently the by-products are more important than the hoped-for results. Research, explicitly, is the re-examination of what is known with the hope of discovering the unknown. In research more than in any other activity, an individual mind, with its viewpoint, acute powers of observation and a dominating incentive, is much more penetrating and effective than is collective effort. To arrive at a truly concerted method of approach to any problem is almost impossible, due to the persistent reversion to personal argumentative ability that finally dominates the less positive or personally interested minds.

The Cooperative Fuel-Research has developed facts of economic importance. It has been estimated that the production annually of an additional 1,000,000,000 gal. of gasoline from crude oil was made possible by changes in specification indicated by this research. How much the actual increase in production has been is difficult to ascertain. The general improvement in vaporizing qualities, the general advance toward uniformity of fuel, the widespread marketing of winter gasolines in the territory north of 40 deg. latitude in the United States, the improvement in the starting-ranges of both winter and summer gasolines, while permitting increased production from a barrel of crude, are all by-products of the cooperative research. During the year much attention has been given to the excellence of California gasoline and all other gasolines made by various processes which have improved anti-knock qualities. This has been one effect of the Society's activities in agitating matters relating to detonation.

Your President is happy to report the findings of Surgeon General Cummings to the effect that tetraethyl lead, if used according to reasonable regulations, is not harmful to public health. The economic importance of this fact cannot be over-estimated and that this fact has been established is a matter of great satisfaction to the Society.

Research has practically arrived at the causes, effects and means for controlling dilution and, while further research is being carried on, the industry has already adopted means for not only controlling but utilizing crankcase-oil dilution. One of the by-products of this work has been the discovery that dilution as such is not harmful, it being harmful only in combination with included dirt. The best advances in engineering have come in the last year through the recognition of this fact; and runs without crankshaft-bearing adjustment have reached 150,000 miles on high-speed motorcoaches.

Research is now being completed on the starting-part of the distillation curve.

Constant discussion has been carried on during the year on Headlighting because of its influence on public safety. Let it be recorded that the opinion of many, including your President, is that this has been most valuable in developing the various viewpoints and

phases of the question. The Research Department enters the coming year better prepared to handle the subject. That research develop scientific facts is essential to the progress in the work; whereas the working out of the facts in production, law making and enforcement are entirely separate questions. This viewpoint seems to have been smothered during the year by too great ardor in behalf of various means for solution of the problem, before the problem was practically understood, to say nothing of its being stated.

The Research Department is active in development of instruments and interpretation of the results of tests of impacts of vehicles on roads.

The question of Riding-Qualities is principally involved in means for measuring the physical causes and their corresponding physiological effects. Some time will elapse before results are available. In the meantime the Society is promoting this subject in papers and engineering discussions, and an increasing interest on the part of the car makers and the public in the question is apparent.

Gears are the eternal problem of the shop man. The Research Department is giving careful study to this subject, with the hope of contributing to the solution of this important mechanical and manufacturing matter.

The earnest devotion of Dr. H. C. Dickinson, of the Bureau of Standards, chairman of the Research Committee, is respectfully recognized and the Bureau's as well as his private contributions to our work is gratefully acknowledged.

I want to commend the fine work of Otto M. Burkhardt, who has completed his first year in this most difficult and valuable work, as Manager of the Research Department.

SECTIONS

The active Sections of the Society now number 13. In the year the Northern and the Southern California Sections have been added. Some of the most interesting developments in the automotive industry have come from the West and others are developing there. It is hoped that our new Sections will honor us by continued contributions to the automotive arts.

The Metropolitan Section dinner during the 1926 New York City Show, at which engineers explained the features of their 1926 models, was an effective innovation and will, it is hoped, be repeated. The production activities of the Detroit Section and the fine character of its papers have been a feature of the year. The excellent work of the Pennsylvania Section at the Automotive Transportation Meeting was one of the outstanding accomplishments of the year.

What can be done by a Section is illustrated by the remarkably successful dinner given by the Indiana Section at the time of the 500-mile Indianapolis Speedway race. In the manner of conducting a Section and in general interest and merit of meetings and papers, Indiana has set a pace that is hard to equal. The Chicago, the Buffalo and the Milwaukee Sections have each had an excellent year. These Sections have great problems owing to the diversified interests of their members. They have met the situation with marked success. Cleveland has had many excellent meetings this year, with wonderful attendance. The Washington Section has shown great vitality during the year and its meeting at which the World Flyers told their story was of great interest. The Washington Section, recruiting its membership from the scientific and technical departments of the Government service, has in its membership some of the Society's most talented men.

The importance of active Section officers and members, who have both the spirit of service and the ability to carry forth the work of the Society, was impressed upon the mind of your President this year.

The need for conducting the meetings according to good rules and practices was apparent in results many times during the year.

The gain of 554 members by the Sections from Jan. 1, 1925, to Jan. 16, 1926, reflects the activities of the Sections and the new way of collecting dues. The improved financial status of the Sections and the lowered cost to the parent Society of supporting the Sections shows the wisdom and effectiveness of the new method of financing the Sections.

Too much cannot be said in praise of the work of the Sections Committee and its Chairman, J. H. Hunt. Likewise, the general activities of the Sections, the number of meetings, the attendance and vigor shown by the Sections at their various centers and the home office, reflect great credit upon Mr. Warner and the Sections Department of the Society.

PUBLICATIONS COMMITTEE

Mention has already been made of THE JOURNAL and the new HANDBOOK, under the heading of financial matters. We must mention here the increasing number of highly valuable papers to such extent as to exceed the capacity of THE JOURNAL and the time available at the meetings. This is making it possible to fill the TRANSACTIONS with the highest class of technical information available in the world on the subject of automotive engineering.

The work of the Publications Committee has been one of care and fine judgment and the text of THE JOURNAL, as well as the papers presented, indicates the value of the work. To Prof. E. P. Warner and his Committee much credit is due.

Some idea of the increasing volume can be had by


J. H. Watrous


R. K. Jack


F. P. Connolly


J. E. Butz

ANOTHER GROUP OF THOSE PRESENT

considering that in 1925 the number of papers presented was 158, in contrast with 125 for 1924. In the latter half of the year 93 papers were presented.

The amount of editorial work involved to condense papers sufficiently so that they can all be reported in fairness to contributors is a problem of serious nature for the Society. The staff of editors is to be complimented in this work.

ENGINEERING MATERIALS

A misconception found among some engineers is that the use of highly expensive and difficult-to-handle materials is a sign of engineering intelligence. On the contrary, the skilful use of the cheapest and most easily handled materials and the attainment of very useful results with them mark the highest achievement of engineering.

The automotive industry has developed grey-iron castings from the condition of an uncertain art to that of a truly scientific achievement. The uses of grey iron are increasing, together with a reduction in prices. Ten years ago, except in the very cheapest of products, new models always had aluminum crankcases and transmission cases; the use of iron was the exception. Today, the use of aluminum is the exception. Prices ranging from 5 to 9 cents per lb. for grey-iron for cylinders and crankcases tells a story of survival or extinction for many a foundry and manufacturer of powerplants. There never was a time when engineers valued more highly aluminum and the lighter alloys, or desired more to use them. The market price, however, is quietly restricting, if not eliminating, aluminum as an automotive material. Except in the case of the most expensive cars and the most specialized purposes, it is disappearing on automobiles. This seemingly most regrettable economic fact is exemplified by the new powerplant models just introduced at the shows. Aluminum, with magnesium alloys, is still necessary for aviation uses.

In the meantime, new grey-irons are being developed whose tensile-strength, elastic-limit and wearing qualities have reached remarkable values. The development in grey iron has been duplicated in malleable iron; the latter material is making a place for itself at the expense of the more backward materials.

Steel, in its various forms, has responded to the fundamental demand of the automotive industry which, as we all know, has been the incentive for developing not only steels of great strength, but the art of heat-treatment. Likewise, as steels have increased in elastic-limit, tensile-strength and hardness, the demands, rapidly and effectively met, for more lasting and effective tool-steels have come. This eagerness to meet the requirements and the ability to do so at fairly reasonable prices commensurate with the results, have been the very foundation of progress in the automotive industry. Without these improvements in this utility, steel, together with the relatively low prices, the industry could not have reached the low-price market. Nobody can say that the steel industry has suffered or wasted away in this process; on the contrary, its automotive business is reaching major importance in tonnage and profits.

The drop-forging art has advanced in many lines, but has improved in unit costs only in spots. Owing to larger and stiffer crankshafts, and the persistently high cost of alloy-steel shafts, the tendency is to avoid using them. The development and perfection of heat-treating on a commercial scale has become an exact science, but the cost has yet to make great strides downward, except in a few plants.

Steel stampings have made the automotive industry. Every year we find our wants supplied at a decreasing cost by the substitution of pressed steel for other materials of construction.

This time in our history may hereafter be known as the rubber year. Some harsh words have been heard concerning the attempt of the British to control the price of rubber. Without attempting to point out the political or economic rights in the matter, in view of our own tariff walls that have been a constant barrier in international trade, let us consider three significant facts:

(1) The price of rubber is a fine example of how little any group can control the consequences when, without exact information on consumption, it lets loose economic forces by restriction of product or price, or interferes with the free flow of the world's supply of raw materials

(2) The most conspicuous violation of the principles of standardization, which has been so valuable to us in all other branches of the industry, lies in the tire policies of the automobile and the tire industries

(3) The shortage and the future shortage of rubber are the greatest possible challenge to our industries and engineers to rise up and meet this rubber question by the very means by which the threatened shortage of fuels was met. Seven years ago we had only 11 years to go on our fuels. Today, due to research, anti-knock fuels and engine developments have doubled the mileage possibilities of the available supplies. Automotive light-weight engines have cut in half the cost of wildcatting for new sources of crude oil. In the meantime, the petroleum industry has taken up standardization, made a more useful product by progress toward uniformity and increased its production of gasoline from the crude, so that its problems have been those of over-production—not shortage. My personal view is that the fuel supply for the human race will not be threatened so long as engineers think and scientists function. The results will in the end put us on a sounder economic basis. There will be relief in standardization and research.

It is significant that decreasing costs and weights are the ends toward which real progress is made. When industries are backward in increasing the utility and lowering the price of their materials, slowly but certainly the world shifts to materials of greater intrinsic value. Backward industries unconsciously hold the old notions of high unit-profits, as against broadening usefulness, low prices and higher over-all profits in the end. This is the great lesson that the engineer, the manufacturer and nations must ever keep in mind. It is a sound economic principle. We live or survive as we recognize and meet it. The Boston Tea Party started a line of consequences that will not cease to evolve. Stated in simpler terms, success comes as we increase utility at the same time we decrease costs; thus intrinsic value in the last analysis is the goal of all engineering and trade.

In measuring our product we must use no misleading yardsticks. What the public wants and buys is the most important fact for the engineer to know. Without this, engineering is a pastime, a hobby, a personal gratification—not a profession. To know people and their desires is a higher purpose than cold mathematics or personal preference in design.

AERONAUTICS

During the year the Society promoted aviation, and the great air-tour was the consequence of its decision to sponsor commercial aviation.

The aeronautic safety-code was completed, and published by the Society, thus becoming available to the world.

Aeronautic engineering was fostered during the year with signal success.

The aeronautic banquet was one of the bright spots on this contentious year in aeronautics.

MOTORCOACHES

The Society has used its good offices by presentation of papers and by standardization to promote the motorcoach. The Society's activities in the last 5 years are a conspicuous example of its policy to get before the members subjects well in advance of indicated development.

PUBLIC SAFETY

The Society, through its meetings and various papers, addresses by public officials and in numerous other ways, has promoted public and highway safety. It now has a committee, consisting of the past, present and elected presidents, whose function is to promote the public-safety activities of the Society. The Society has cooperated with the Federal, State and municipal authorities on the question. Many elements of design of cars at the Show, such as narrowed wind-shield columns, better brakes and better headlights, are results of the campaign in this public matter.

CONCLUSION

In closing my book of the year, let me thank the Council, the Chairmen, the Committees and the Members for the high honor you have given me this year in permitting me to serve as your President. No accomplishment would adequately express my appreciation. Words are feeble. To have known the men of the Society and to have worked with them, would have been adequate, but to have been your President leaves me with the most cherished of memories.

Standards Committee Report

In the absence of Chairman E. A. Johnston, Manager R. S. Burnett, of the Standards Department, presented the annual report of the Standards Committee, as approved by the Council. This is summarized elsewhere in this issue of The Journal. Upon motion, duly seconded, it was voted unanimously that the report be approved for submission to letter ballot of the voting members of the Society.

Constitutional Amendment Proposed

J. F. Winchester stated that during the last year there had been some discussion by a group of men within the Society who felt that they would like to be represented by a Vice-President of the Society. This group of men consists largely of those who are in the operating and maintenance end of the business. During this period the question had been discussed also as to the advisability of discontinuing the Vice-Presidency representing stationary internal-combustion engineering.

Mr. Winchester expressed the understanding that it has been practically agreed that the group within the industry representing stationary internal-combustion engineering is very inactive and referred to the fact that Vice-President Scott, representing that group recently advised discontinuing the Vice-Presidency occupied by him.

Mr. Winchester submitted the following constitutional amendment:

> I propose that paragraph C29 of the Constitution of the Society be amended by changing in line six thereof the words "stationary internal-combustion" to the words "operation and maintenance."

The effect of this would be to substitute for the Second Vice-Presidency representing stationary internal-combustion engineering a Second Vice-Presidency representing operation and maintenance engineering.

The Council of the Society, at a meeting held on Jan. 25, 1926, passed a unanimous vote in favor of this constitutional change.

This proposal was seconded at the Society Business Session by B. T. Lemon, and will be mailed by the Secretary to each member of the Society entitled to vote, 60 days previous to the 1926 Summer Meeting of the Society, to be discussed and voted on at the latter meeting.

The following communication from W. H. Conant, dated New York City, Jan. 23, 1926, was read:

> As I find I will be unable to attend the Annual Meeting this year, will you not be good enough to have presented for me the following amendment to Section C46 of our Constitution?
>
> Strike out all after the first semi-colon, beginning with the words "and three members of the Society. . .", so that C46 would then read:
>
> NOMINATING COMMITTEE
>
> The annual Nominating Committee of the Society shall consist of one member of the Society elected from and by each Section of the Society prior to the Semi-Annual Meeting.
>
> It is my recollection that I had some part in arranging the method by which our Nominating Committees are formed and it may not be inappropriate, therefore, for me to suggest a change now.
>
> At the time the present method of Section representation was written into the Constitution there were but four Sections of the Society and by electing three members-at-large to represent the non-Section part of our membership by sitting with those selected from each Section, a proper balance was struck in a committee of seven. With the great increase in number of Sections, two changes have come to the Nominating Committee. First, the proportion of members-at-large is so small as to make it less of a balancing force, and, second, the much larger number of committee members now sent from the Sections makes the committee so representative of the Society's whole membership that there is less need of members-at-large unless more of these were to be added, which would make the committee unwieldy in size.

[Mr. Conant's proposal did not meet with a sustaining second.]

President-Elect Lítle's Remarks

President-Elect Thomas J. Lítle, Jr., who was called upon to make a few remarks at this time, said in part:

> I appreciate the great honor you have conferred on me. I believe that this Society today is by far the greatest technical society in the world. The automotive industry is today the world's greatest industry, and that the Society, representing that industry, should be the greatest society, not speaking from the

Among Those Present
G. Waine Thomas and S. A. Jeffries, Reo Motor Car Co.

standpoint of numbers, but from the standpoint of activity, real live subjects and the good that you do in a technical way in your meetings, is only natural.

I have appreciated association in this Society very much. It has been very, very helpful, and it can be very helpful to anybody that comes into the Society with the idea that he is going to get something out of it. And I assure you that every member who wants to can get much more out of the Society than he ever puts into it. It will be very helpful, particularly in the case of the young men. The young men of our industry should be encouraged to participate actively in the Society. No other connection could help them so much. We need more young men in the Society, and you captains of industry who are sitting in the room today should see to it that your young men in your engineering and production departments are more active in this work. There is, in my estimation, no way of advancing more rapidly in the industry than by actively participating in this Society.

We have had great prosperity in the last couple of years and we hope that it will continue. There is no reason why it should not, because our industry is going ahead by leaps and bounds and we hope that our meetings will be better and better.

I have been much interested in the meetings as Chairman of your Meetings Committee for the last 2 years. It is possible to have better meetings. We get new information. The meetings, as you know, now are staged as lectures of the popular type, so that we can all understand what is being discussed and so that crowds will be attracted because of the interesting programs announced.

We recently have been illustrating our lectures, exhibiting models and laboratory apparatus. This obviously makes the meetings more interesting. We will continue that policy.

The production end of the business has been given considerable thought by us. We have drawn production men into the Society and arranged meetings for them.

Certain groups of students in colleges are now interesting themselves in our work. At least two colleges in this Country have regular automotive engineering courses. In those colleges THE JOURNAL of the Society is used as a part of the course, as a textbook. Our proceedings are watched very closely by those young men.

We college men in the Society owe it to our own colleges, I think, to interest them and keep them up-to-date on our work. If we remember that, whenever we have the chance to call attention to our Society in these colleges, we will build for the future. We must have the college men in our work. We need more of them. We need more engineers all through our industry, not only in the engineering department and the drafting room, but in the shop, because they will eventually work up to be executives.

Many of our executives have not the technical training they wish they had. All of them appreciate the assistance of these young fellows who are coming up through the ranks. If I were to advise you, I would say you had better send your son who may have graduated recently from college into the shop and let him work his way up through the plant. It is just as important as sending him through the engineering department.

As to the future of our industry, the future work of the engineer, I think we should bear in mind, as I said at the dinner in New York City, that we still have a wasteful system in the production of the motor car. Our modern engines are not efficient and their efficiency has not been increasing very much lately. We have wonderful possibilities for improvement. We are throwing away too much power. When the inventions come along, no matter how crude they may be, you should take them and perfect them. In conclusion, I want to say again that I appreciate the honor you have conferred upon me.

REPORT OF THE TREASURER

In addition to submitting figures of income and expense for the calendar years 1924 and 1925 and corresponding figures for the last 3 months of those calendar years, Treasurer Whittelsey summarized the operations for the fiscal year ended Sept. 30, 1925, as follows:

- Budget Income for 1925, $302,000
- Actual Gross Income, $305,440.76 ($3,440.76 over Budget)
- Net Actual Operating Income, $217,845.54
- Budget Expense for 1925, $313,500 ($11,500 over Budget Income)
- Actual Expense, $305,034.71 ($8,465.29 less than Budget Expense)
- Net Operating Expense, $217,439.49 ($406.05 less than Net Operating Income)
- Assets over Liabilities, $162,360.33 ($159.82 less than on same date in 1924, due to adjustments affecting prior period)
- Securities (cost value) on deposit with Chemical National Bank of N. Y., $126,260.63 ($7,379 less than in 1924; $28,460 more than in 1923; due to conversion of securities to defray current expenses just prior to accrual of annual dues)

COMPARATIVE BALANCE SHEET AS OF DEC. 31, 1924, AND DEC. 31, 1925

Assets	1925	1924	Increase	Decrease
Cash	$27,927.06	$41,737.26	....	$13,810.20
Accounts Receivable	39,128.03	33,112.29	$6,015.74	....
Securities—Cost Value	145,875.13	133,639.69	12,235.44	....
Accrued Interest on Securities	1,638.05	1,634.51	3.54	....
Inventories	9,666.38	9,537.32[a]	129.06	....
Furniture and Fixtures	5,917.61	6,880.14	....	962.53
Items Paid in Advance, Charges Deferred	8,334.36	12,653.99[a]	....	4,319.63
TOTAL ASSETS	$238,486.20	$239,195.20	....	$708.58
Liabilities and Reserves				
Accounts Payable	$7,507.61	$6,822.31	$685.30	....
Dues and Miscellaneous Items Received in Advance To Be Credited Monthly	61,590.17	57,505.75	4,084.42	....
Reserve Set Aside for Anticipated Expense	8,234.30	17,673.95	....	$9,439.65
General Reserve	157,193.19	146,721.42	10,471.77	....
Unexpended Income	3,961.35	10,471.77	....	6,510.42
TOTAL LIABILITIES AND RESERVES	$238,486.62	$239,195.20	....	$708.58

[a] Corrected figures.

Net Operating Income for 1925, $13,583.57 less than in 1924, due principally to falling off of advertising sales, during the first half of the fiscal year

Expenses for 1925 increased about $8,500 over 1924, due to increased cost of publications, increased cost of research work and increased cost of meetings. General office expenses were $1,643 less in 1925 than in 1924

The fact that the Council, upon recommendation of the Finance Committee, has authorized a budget of $330,500 for 1926 clearly demonstrates its confidence in the continued growth and stability of the work of the Society. This sum will be used to finance your activities in solving problems for the advancement of the automotive industry.

POLAR FLIGHTS SHOWN IN MOVIES

MacMillan Expedition Pictures Shown in Address on Amphibian Development

Fascinating motion pictures of north polar lands never before seen by man and taken from heights of between 5000 and 6000 ft. from the amphibian airplanes used by the MacMillan expedition last summer were shown to an audience of 300 or more at Tuesday night's session in connection with the address given by Grover C. Loening on the development of the amphibian airplane. The motion pictures showed the loading of three airplanes on the ship Peary at the Boston Navy Yard, their landing, assembling and launching at Etah and flights at Etah and over the Greenland ice cap and the mountains and fjords of Ellesmere Land. They revealed the impossible character of the country for landing and taking-off with airplanes from either water or land.

The motion pictures, which concluded the address, were led up to by a review of the development of the land-water type of airplane by Mr. Loening, who showed many lantern slides, beginning with the flight of Wilbur Wright over the Hudson River, in 1909 during the Hudson-Fulton celebration, in a Wright airplane to the bottom of which was tied a canoe for landing on the water, and culminating in pictures of the Loening amphibian with which Lieutenant McDonald had established four new world's seaplane records the preceding Saturday and had made a speed of 111 m.h.p.

Trend of Amphibian Development

The general trend of development was shown to have been the obvious one of adding floats to land airplanes or adding wheels to flying boats, with the net result of added complication, head resistance and weight. Faults of the early types of pusher machine with the engine above the pilot and with the conventional type vertical engine, such as high center of gravity, limited range of the gunner in combat machines, drag of the wheels in the water, and so forth, were pointed out. Analysis of these faults led, in the development of the Loening amphibian, to probably the first definite recognition that to make this type of airplane successful required the initial design of a totally new type that would be amphibious in conception and complete in the proper characteristics for either land or water operation. In this new type, an airplane with exceptional qualities of its own, were it never to alight on water, and a desirable tractor type of flying boat full of seaplane advantages, were it never to descend on land, has been obtained.

Vital characteristics of the Loening amphibian are obtained by building the body and hull as a unit, which gives an extraordinary amount of room for useful load; by using the new Packard inverted airplane engine, which greatly lowers the height and center of gravity and gives the pilot unusual visibility; a high angle to the base of the hull, which raises the nose 6 or 7 ft. above the water and enables the machine to encounter rather rough seas successfully; and folding landing wheels that can be retracted by an electric motor and housed well above the water. Motion pictures were shown of the wheels being raised and lowered while in flight. The upper part of the machine greatly resembles land airplane construction, the wing construction being practically the same as in the DeHaviland. The framework is of wood and the hull construction is entirely covered with duralumin fastened by duralumin bolts to wooden stringers, great care being taken, however, to separate the metal sheets from the wood by a layer of fabric impregnated with bitumastic. Wings are of metal framing covered with linen and the ribs are of duralumin.

After the construction in 1924 of a preliminary model for testing, work was started on a machine for the Army Air Service and the first of a group delivered in January, 1925, proved definitely in the air the claims that with the same powerplant and 100 or 200 lb. additional weight, it could outfly, out-maneuver, out-climb, and out-speed the Army's DeHavilands, said Mr. Loening. Since then, 17 of these amphibians have been completed and put to work in all climates from the Arctic regions to the tropics and for a wide variety of uses. These airplanes have alighted on the water with the wheels lowered and on mud with the wheels raised and have taken off from the mud with the wheels raised, all without any mishap.

E. P. Warner

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Grover C. Loening

At the Left, the Chairman of the General Session and, at the Right, the Author of the Paper Presented Thereat

This "Pair of Birds" Represented the Army at the Annual Meeting

Capt. T. E. Tillinghorst and Lieut. C. W. Bettis, Winners of the Pulitzer Trophies

THE NAVAL AIRCRAFT FACTORY SENT THESE TWO MEMBERS OF ITS STAFF TO THE MEETING
J. H. Geisse, at the Left, Is Senior Engineer in the Aeronautical Engineering Laboratory, and C. S. Fliedner, at the Right, Holds the Position of Associate Engineer in the Laboratory

INTERESTING COMMERCIAL USE FORESEEN

The most interesting and important application of the amphibian foreseen by Mr. Loening is in commercial work and he looks forward to a time when all airplanes will be of this type, which will ensure safety from drowning in event of a forced descent upon water, will make the construction of many costly landing-fields unnecessary and greatly reduce the time between cities. With an amphibian the Air Mail or a business man could land in the Hudson River at New York City within a short distance of the Grand Central district, in the St. Clair River at the foot of Woodward Avenue in Detroit and in Lake Michigan at Grant Park in Chicago. Thus the long runs by truck or automobile from outlying landing-fields would be obviated.

Throughout most of the Country fine natural airways exist over the Hudson River, Lake George and Lake Champlain to Quebec; up the Mississippi River from New Orleans to Minneapolis and St. Paul; all along the Atlantic seaboard; in the Gulf of Mexico; and in California. Even in the Rocky Mountains water landings could be made all along the Air Mail route by diverting the route only 18 miles. Good water landings are available all along the Air Mail route as far west as Cheyenne.

Picturing the private use of airplanes by business men, Mr. Loening said that concrete ramps could be built into the water so that the amphibian could alight on the water, taxi up the ramp and park on the land, a suggestion that brought a laugh from his hearers but was put forth seriously as entirely feasible. The speaker said that he was now working for such a landing construction in New York City.

Arthur Nutt — Dr. Karl Arnstein
THE PRESIDING OFFICER AT THE AERONAUTIC SESSION (LEFT) AND THE PRINCIPAL PARTICIPANT IN THE DISCUSSION (RIGHT)

METALCLAD AIRSHIP DEVELOPMENT

Discussed at Aeronautic Session; Airplane and Airship Economics Compared

Two features having distinct and almost proverbial controversial tendencies were evident in the session devoted to aeronautics which was held on Wednesday morning, Jan. 27. Respectively, they are the comparative merits of lighter-than-air and heavier-than-air craft, considered in their economic aspects, and the advantages and disadvantages of metal versus fabric or composite material as a covering for airships. Consequently, the numerous members and guests who attended doubtless were stimulated to greater concentration in following the presentation of the two lengthy papers scheduled, these being the Economic Spheres of Usefulness of Airship and Airplane, by Humphrey F. Parker, and Metalclad Rigid Airship Development, by Ralph H. Upson, both of which are printed in full elsewhere in this issue of THE JOURNAL.

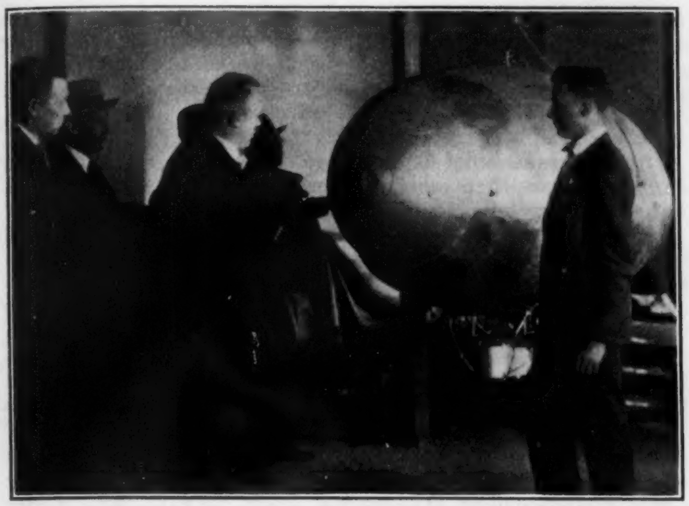
VALVE SYSTEM OF THE SHENANDOAH

In the course of presenting his paper Mr. Parker interpolated additional statements regarding the Shenandoah disaster. He said that the usual procedure on rigid airships has been to provide every cell with an automatic valve, but in this case changes were made in the valves, manual valves also being used for the discharge of gas when crossing pressure height. The cell with the automatic valve remained unchanged, but the cell not having an automatic valve was

H. F. Parker — R. H. Upson

equipped with a maneuvering valve of adequate area and, in addition, an opening to a cell equipped with an automatic valve so that, if the maneuvering valve should fail to function, gas could still escape. According to Mr. Parker, however, this reasoning is superficial. He went on to say that the sole purpose of an automatic valve is to function in emergency without attention. In a valve system such as the Shenandoah's, the possibility must therefore be faced that a maneuvering valve would fail to open, and it must be remembered that the safety of the ship would then depend on the remaining provisions, in themselves, being adequate to permit the escape of gas fast enough. He then considered the gas pressures that would be caused automatically in the cells of the Shenandoah, with valves arranged as on its last flight, and compared these with pressures that would occur under similar conditions with cells having the usual valve arrangements. Along this line, he reached the conclusion that the pressure in the cell without an automatic valve becomes between six and seven times its original maximum.

He also referred to the fact that the Shenandoah was filled with helium, which is a denser gas than hydrogen, and said that this increase in density would cause an increase in the other pressures of 50 per cent, since the valves of the Shenandoah were similar to those used on the German Zeppelins and were designed for ships of that type inflated with hydrogen. German experience indicates that valves of the

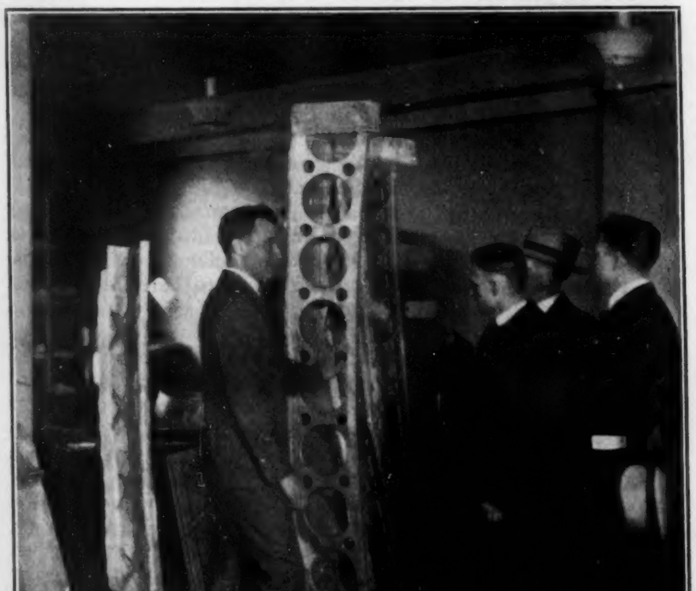


Demonstrating the Water Model of the MC-2
This Is Probably the Largest Water Model of an Airship Ever Built. When Hung in an Inverted Position and Filled with 5125 Lb. of Water, the Equivalent of a 400-Per Cent Overload on the Full-Size Airship Was Obtained

type originally on the Shenandoah were just adequate to meet the worst conditions. With possible pressures 10 times as great as the worst experienced in German practice, pressures undoubtedly far in excess of the breaking load, anything might have happened in emergency. The automatic valves alone being inadequate to prevent the bursting of a cell, the conditions can be compared to those of a steam boiler in which safety against explosion is dependent upon the opening of a hand valve by an operator shortly before the explosion is expected. Mr. Parker said further that the relative responsibility of the valves and of the storm for the loss of the Shenandoah probably will never be determined, but he feels that to lay the blame on the craft, knowing that the foregoing conditions existed, is hardly fair.

German Experience With Metal-Covered Airships

After Mr. Upson had presented his paper, Chairman Arthur Nutt, of the Curtiss Aeroplane & Motor Corporation, Buffalo, called upon Dr. Karl Arnstein, vice-president of the Goodyear Zeppelin Corporation, Akron, Ohio, to present his views on the type of construction described by Mr. Upson. Dr. Arnstein spoke from experience, having been engaged for more than a score of years in the design of airships of the Zeppelin type. He said that he does not know of any better covering for an airship than one composed of fabric, dope and metal. He stated that it has never been necessary to replace the outer covering of a Zeppelin airship. Referring to the type of airship designated by Mr. Upson as the MC-2, he questioned the tightness of the metal seams. Regarding the statement that has been made to the effect that the outer covering of a fabric-covered airship is a liability and not an asset, he said that fabric can be made fireproof: in fact it is sufficient if the covering is of non-burning construction, that is, if it does not itself support combustion. He asserted that an airship of the Zeppelin type has ample strength, and has a covering superior in strength to one composed of metal sheets. He also discussed the likelihood that fabric will tear, electrical conductivity and possibilities of damage due to electrical conditions, the effects of humidity, and other matters pertaining to possible detrimental effects. According to his experience, the water absorbed by the fabric covering of an airship of the Zeppelin type is practically negligible.



Inspecting the Kind of Structural Members Used in Metal-clad Airships
A Feature of the Aeronautic Session Was an Inspection Visit to the Laboratories of the Aircraft Development Corporation

Dr. Arnstein doubts the efficacy of a "one-skin" airship such as is proposed by Mr. Upson in his MC-2, and enlarged upon his reasons for this belief as regards susceptibility to damage and consequent failure. He brought up the likelihood of corrosion of the metal and the difficulties of maintaining adequate inspection of an airship of the MC-2 type, citing the possibility that moisture will collect and condense on the inside surfaces. He thinks also that a very serious objection to the "one-skin" type lies in the vulnerability of its hull, which is so easily subject to damage as to allow the escape of buoyant gas, especially helium. He spoke of the difficulties of making repairs and of the necessity of deflating the airship to make the interior available for inspection and mentioned that all parts of an airship of the Zeppelin type are accessible, making repairs during flight being even possible. Among the other points covered by Dr. Arnstein in comparing the two types of construction were the factor of safety provided, the design of the sections, the problems in regard to the shape of the craft, whether long and lean or short and fat, stability, performance in curved flight, the arrangement of the fins, and kindred matters.

In reply to Dr. Arnstein, Mr. Upson cited his experience about 5 years ago when exposure tests of fabric were made under his supervision. At that time, the factor of depreciation was 30 per cent. He said that, while one would expect fabric to deteriorate faster under winter conditions, the fact is that it deteriorates most rapidly under summer conditions. He discussed the relative amounts of skin friction with fabric and with Metalclad covering and answered the objections raised by Dr. Arnstein to the Metalclad construction, citing tests that have been made to substantiate his statements as to corrosive and other tendencies toward deterioration. In addition, Mr. Upson read statements made by various authorities in this Country to the effect that practically no danger from lightning due to Metalclad construction would be invited.

Research Laboratory Visited

At the close of the session, an opportunity was offered by Mr. Upson to the members and guests for inspection of the research laboratory of the Aircraft Development Corporation, located in the General Motors Building, and many availed themselves of this privilege. Representatives of the Corporation were present to show and to explain the equipment and the lines along which research is progressing.

Not the least interesting of the processes is that by which the duralumin sheets are riveted together. A machine has been devised by one of the members of the organization which rivets the sheets together in a manner that is very similar to the operation of a sewing-machine. The rivets are spaced almost as close as the stitches made by a sewing-machine and the device is very positive in its action.

Each seam has three rows of rivets and will withstand a pull of 650 lb. The duralumin sheets are 0.008 in. thick.

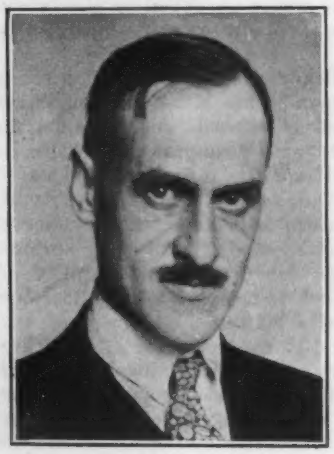
A model of the MC-2 was exhibited and the various features of its construction were explained. A device for testing the effects of vibration upon the riveted seams was also demonstrated.

Various types of airship girders, struts, frames, and the like were on exhibition and, through the courtesies extended, the visitors were afforded an unusually good opportunity to gain information at first hand and to supplement it by the added information that resulted from their questions.

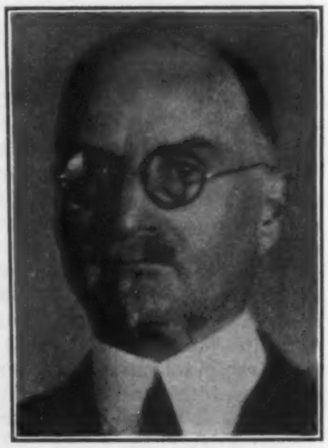
LARGE ATTENDANCE AT BRAKE SESSION

Aim of Papers Presented Is Better Understanding of Failures and Noises

That the subject of brake performance is one of keen interest to motor-car engineers was evidenced by the large and attentive audience and the thorough discussion elicited by Chairman Carl Breer at the Brake Session on Wednesday



H. H. Allen



F. C. Stanley

afternoon. H. H. Allen, of the Bureau of Standards, in his paper, Effect of Change of Temperature of Brake-Linings on Their Performance, dealt with the effects produced by certain known causes; Dr. F. C. Stanley, of the Raybestos Co., followed the opposite course of reasoning and, taking the phenomenon of brake squeaking, traced the reasons for it and recommended remedies. The general discussion from the floor, which followed the presentation of the papers, partook somewhat of the nature of an experience meeting, with the recounting by men interested in brake design and brake performance of some of their findings in this field.

Factors Affecting Brake-Lining Efficiency

The data presented by Mr. Allen were gathered in an effort to bring about a better understanding of conditions that lead to sudden and serious reduction in the retarding ability of brakes. When brakes become less effective because of ordinary wear in the brake-linings or other parts, the change is gradual, and serious results can readily be prevented by periodic inspection and adjustment. However, emergency losses in brake effectiveness, even though temporary, may prove disastrous and should be guarded against, possibly by some change in brake design, certainly by a better understanding on the part of the operator of the conditions affecting retarding efficiency.

The factors affecting brake-lining efficiency covered in Mr. Allen's investigation were rise in temperature and saturation with water and with oil. Laboratory tests have already yielded much information in this connection, and these tests were paralleled by a series of experiments undertaken with a view to securing data on the working conditions and operation of brakes on a passenger car in actual service. In this work a determination of the true coefficient of friction of the brake-lining was not thought necessary. Findings were made in each case of "the apparent coefficient of friction," or the ratio in which the pedal pressure and the total decelerating force at the periphery of the brake-drums are involved.

In the tests a modern passenger-car fitted with four-wheel brakes was used. To test the effect of rise in temperature, the car was run approximately ¼ mile at constant speed, with the brake pedal depressed to a fixed stop. Temperature readings were then taken of thermocouples set in the linings of each brakeshoe. Deceleration was indicated by a recording decelerometer and the pedal pressure by a gage attached to the brake pedal. The process was repeated at each of several brake-pedal pressures up to the maximum at which the engine would carry the load.

To illustrate the results obtained, Mr. Allen threw on the screen slides picturing curves in which the apparent coefficient of friction was plotted against temperature. The curves depicted the variation of this coefficient in percentage of its value at 100 deg. cent. (212 deg. fahr), the selection of this figure as unity having been made as it approximated the lowest temperature for which data were secured. The apparent coefficient of friction was found to vary, with a rise in temperature, at a rate varying from the minimum of about 5 per cent to the maximum of about 50 per cent per 100 deg. cent. (180 deg. fahr.). Only one lining, one without a saturant, showed an increase in the apparent coefficient of friction with rise in temperature. This difference in behavior seems to indicate, said Mr. Allen, that the decreases in the coefficients of friction of the finished linings are largely, if not altogether, due to the influence of the temperature rise of the saturant.

In another series of tests the linings were thoroughly drenched with water. The method of effecting this was to run the car through a number of fords in a creek in Rock Creek Park. To make sure that the linings had become thoroughly drenched with water, the car was run backward and forward through these fords as many as 12 or 15 times. Successive decelerations were then made, the same measurements being taken as in the tests involving rise in temperature. The decelerations were all made at one position of the brake pedal. The curves showing the results of these tests indicate that a general increase in the apparent coefficient of friction takes place with successive decelerations, although the rate of this increase varies to some extent. The principal difference pointed out was the more rapid rise of the apparent coefficient of friction of the so-called rubberized linings as a result of the first few decelerations.

The final factor affecting the efficiency of brake-linings to be tested was the presence of oil. After the linings and drums had become thoroughly dry from the previous test, they were treated with liberal potions of oil, and another series of successive decelerations, similar to those made with the water-soaked linings, were made. This series of tests showed much smaller differences between linings than was the case with the water-soaked linings. Linings, regardless of their character, did not seem to be able to recover their previous frictional properties in from 10 to 16 decelerations.

Why Brakes Squeal

Dr. F. C. Stanley brought to his more general subject, Causes of and Remedies for Brake Squeaking, a wealth of concrete facts based on experiment and experience. After outlining an investigation conducted with the Carson brake-lining testing-machine, Dr. Stanley stated his conviction as to the nature of brake squeaking in the following theorem: Brake squeak is undamped or unmuffled drum-vibration caused by the plowing action of metal or grit in the lining. To support the general basic statement, Dr. Stanley then traced the action of the 15 known methods of silencing brake squeak. Three of them were found to introduce lubrication, which stops the plowing action of the abrading particle. Rubber liners, another remedy sometimes used, dampen vibration by furnishing a cushion into which the abrading particle sinks. The use of metal shims was characterized as an attempt to apply pressure at a point exactly opposite the abrading particle and thus to muffle drum-vibration. The same effect, that of muffling drum-vibration, is said to follow from other silencing expedients adopted:

rounding of the bands, removing brass wire and bearing rivets, smoothing the drum, and other methods commonly used.

By no means all of the 15 expedients used to silence break squeak which were mentioned by Dr. Stanley received his endorsement. He specifically spoke of the use of lining without brass wire as one method that should not be considered. A soft lining, he said, requires more frequent adjustment and is less durable. The application of a lubricant, brake juice or dope gives a temporary relief, said Dr. Stanley, but may cause very serious after-effects. The liquid applied gathers dust from the road or abraded asbestos, the lining grabs, and this grabbing with its disastrous effects on the running mechanism of the car is apt to prove a more serious offender than the original trouble. Dr. Stanley recommended that if any lubricant is to be employed, it should be dry powdered graphite which will act as a temporary remedy and will never gather dust and grit as will oil or grease.

A double set of remedies was given by Dr. Stanley for the cure of brake noise. In the first he went to the base of the problem, and made, for the benefit of the manufacturer, a few fundamental recommendations as to brake design. The other set was addressed to service-stations, and consisted of a number of concrete suggestions as to various things that might be done to a squeaking brake in the effort to reduce it to silence. Some of them were frankly characterized as makeshifts, others were designed to correct errors in the brake mechanism due either to faulty construction or to the effect of wear.

Interest in both papers was shown in the number of questions put to elicit more detailed information as to test procedure and results. During the course of the discussion Mr. Allen brought out the fact that if the tests described by him were carried out several times under the same conditions, they would yield the same results as those shown in the curves he presented. He said that in his belief the water-soaked linings were free from grit, due to the manner in which the water was applied. All the fords over which the cars were run were brick-paved, and the subsequent tests were made on asphalt-surfaced roads. He explained that no experiments were carried on when only a slight amount of moisture was present on the brake-linings, the reason being that to apply the same limited amount of moisture in a number of cases would present almost insuperable difficulties. To produce the same conditions for all linings when they were to be completely soaked was comparatively easy.

One unusual point brought up in the discussion of Dr. Stanley's paper was the presence of frictional electricity in motorcoaches caused by the application of the brakes. This was said to be present to so great an extent in some vehicles as to cause a shock to passengers taking hold of handles in boarding or leaving. No remedy was suggested for this difficulty. Another piece of experience cited from the motorcoach field was that of a company which had been troubled by brake squeaking for a number of years. The brakes used were of the internal-band, full-wrapping type. The defect was finally remedied by removing a portion of the lining directly opposite the point of maximum contact, and this is now the standard practice in the company in question.

Dr. Stanley was asked to state his experience with the comparative wear of a lining when used on a hard and a soft drum. In answering, he explained that lining is worn very much more rapidly on the soft drum and pointed out samples of drums and linings. The soft drum was shown to have become compressed and worn away by scoring. He also said that if temperatures are kept sufficiently low, the drum does not score, and hence the soft drum is not so decidedly subject to wear. In a hilly country, however, high brake-temperatures can hardly be avoided.

COLOR FINISHES AND PIGMENTS

Artistic Use of Colors and the Nature and Sources of Pigments Explained

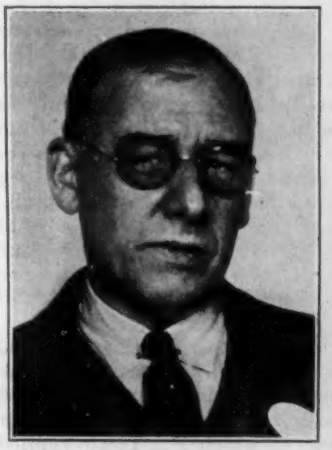
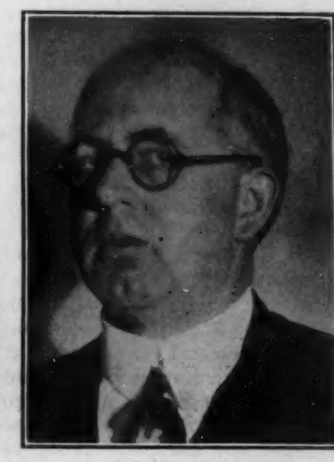
That color finishes are coming into vogue on private passenger-cars and motorcoaches as well as on taxicabs, and


Charles A. Greene H. Ledyard Towle
AUTHORS OF THE TWO PAPERS PRESENTED AT THE BODY PRODUCTION SESSION

how the use of color combinations can alter the apparent dimensions of the car were pointed out at the Body Production Session on Wednesday afternoon by H. Ledyard Towle, of E. I. duPont de Nemours & Co., and the derivation and nature of color pigments was explained and most interestingly demonstrated by Charles A. Greene, color expert of Valentine & Co. The paper is printed in full in subsequent pages of this issue of THE JOURNAL. The demonstrations made by Mr. Greene are, however, impossible of reproduction. Considerable discussion followed the delivery of the addresses notwithstanding the fact that the color finishing of cars does not lie strictly within the province of the automotive engineer, although it has an important bearing on the lines and appearance of the finished vehicle.

In connection with his address, Mr. Towle showed a number of lantern slides, some in black and white, to explain the massing of colors and the placing of light and dark colors to alter optically the dimensions of the car, and others in colors. The latter were from designs by several artists who had been asked by Mr. Towle to present their conceptions of car design and color effects. Most of the latter were remarkable creations and impractical from an engineering and operating standpoint, but several embodied ideas that have some merit and that may be put into effect at some future time. One such idea, for example, is the breaking up of the complete circular lines of the wheels by extending the outer flange of the fenders downward in the form of a curved apron to conceal the upper segment of the wheels and tires.

By the black and white sketches Mr. Towle explained that the apparent length of a short-wheelbase car can be increased considerably by placing a light line at the base molding and extending from the rear of the body in a straight line across the hood to the radiator and even across the side of the radiator. This is the longest straight line in a car and the eye is

G. J. Mercer F. E. Watts
TWO OF THE DISCUSSERS AT THE BODY PRODUCTION SESSION

centered upon it by a light band of color, since the eye registers first upon the lighter colors, and this line gives the eye an uninterrupted sweep from end to end of the car.

Height can be reduced in appearance by dark wheels and dark body below the lower belt molding, and by a dark top with a lighter color on the body side between the windows and the lower belt molding. To avoid a detached box-like appearance of the upper part of the coupé body, the upper part should be in one or two colors that are darker than the lower part of the body and should be closely linked up in color tone with the top of the shroud and the rear deck. It was shown by slides also that in phaetons and roadsters it is advisable to have the upper part dark and the lower part of the body of lighter shade, since a light belt between the dark lower portion of a touring car, or phaeton, and the black top and heavy mass of passengers and shadows under the top gives a fragile appearance to the upper part of the body. In general, dark colors seem to reduce size and light colors to increase size. Some of the roadsters at the show seem much larger than they really are because they are finished in a single light color instead of solid black or blue or the lines are broken up by two or more strong colors.

Members Seek More Facts

In opening the discussion, Chairman K. L. Herrmann said that the information given by Mr. Towle was especially valuable because the industry had not before had such a discussion of color effects; and that some years ago, when he had occasion to make a little study of the subject, nothing had been published that could be used so that he had been obliged to go to the interior decorators' art, where he had no trouble whatever in finding various color schemes for rooms and homes that blended and harmonized. European car builders have been far ahead of the American builders in the matter of color, he said, and it was a relief to get on the other side and see something different from the somber black of the cars in this Country.

The question of color application to motorcoaches was raised by Mr. Hasselgues, and Mr. Towle replied that only the previous week he had suggested some color schemes not only for motorcoaches but for ambulances and hearses; and he showed the audience several panels of color schemes for coaches, which were for particular machines and were not recommended for other vehicles, as he thought cars should be dressed individually just as we dress ourselves and our homes individually. Cars should be listed for color schemes according to the model and the people who are to buy it. A city motorcoach, he thought, should be somewhat dark and simple so that it would not shriek out in the quiet tones of the city streets, but a country vehicle could be brighter to comport with the brighter rural colors. In general, for the motorcoach, he suggested either more than one color or one color in different tones, depending upon the type of vehicle.

G. J. Mercer inquired whether a light color on the roof, such as maize, would make the car look lower, to which Mr. Towle responded that either light blue or gray would blend in with and reflect the sky. Answering further questions, he said that local differences in preference for colors were disappearing, that light gray is not now a perishable color whereas the lakes and ultramarine blues are the most perishable. F. E. Watts inquired whether the theory of dynamic symmetry could be applied to the coloring of motor cars but Mr. Towle said that the first such application of which he had heard was to the Chrysler Six but that he had found that he could get along with composition without the use of a mathematical formula. Answering H. Strickland, he said that to finish a car so that it would blend with the colors of nature both summer and winter he would take the mean of the color tones in the two seasons, which might be a blue or beige or the clear color of sand or dust but would not be a pronounced color.

Mr. Freeman remarked that a well-known artist once told him that an automobile should be masculine and should look broad in the chest and narrow in the hips, and he asked whether colors could not be used to make the car look broader in front and narrower at the rear, to which Mr. Towle replied that he thought they could be. Mr. Wilkinson referred to a book he had seen on colors for taxicabs and said he did not think he would want to apply them to a private car, to which Mr. Towle responded that he was about to issue a second book that includes color combinations in two and three tones for private cars.

How Pigments Are Obtained

An enthusiastic reception was given to Mr. Greene, who made his demonstrations while talking. With a table covered with beakers, bottles and metal panels, he first showed two panels partly covered with bright green finish. The effect of lack of permanency was revealed by the way in which the two halves of the paint band on one had faded to different tones by exposure to ultra-violet rays. Solubility of one pigment and the insolubility of another were shown by dropping small quantities of purple pigments into a solution, the insoluble coloring matter causing no discoloration of the transparent liquid while the other instantly spread throughout the liquid and changed it to a deep rich color. How this solubility resulted in bleeding in finishes was made evident by a pair of panels on which bands of white had been spread across diagonal lines of red. In one panel the red had worked up into the white and showed plainly, whereas in the other the white band was opaque and concealed the red.

An example of covering black and white with chrome yellow and pale Dutch yellow was presented on another pair of panels, by which it was evident that the chrome yellow gave a much more solid coloring. Referring to gravity and texture, the speaker called attention to the lightness and softness of lampblack as compared with the heaviness and hardness of carborundum. Celluloid cylinders were displayed to show the colors that were obtained from the ground by the ancients and were very solid, permanent and economical colors.

Synthetic production of pigments was next illustrated by mixing a solution of lead acetate with bichromate of potassium, which produced a chrome yellow solution from which chrome yellow pigment is obtained by pressing through a filter. Some caustic soda was then added to the solution and stirred rapidly, changing the color from light lemon to orange, which, it was explained, could be brought down to a red. Pulp Chinese blue was added to the chrome yellow and a chrome green obtained. Mixing of the yellow and blue pulps in solution in this way gives a better green tone than can be secured by grinding the yellow and blue pigments together in lacquer. Iron blue solution was made by combining salts of iron with cyanides. When first mixed these resulted in light blue but, when an oxidizing agent was added, a dark blue, such as Chinese or Prussian blue, was obtained.

Maroon was obtained by pouring an amaranth maroon dye and some blanc fixe powder into liquid and adding barium chloride, which precipitated the dye upon the powder base. This presented only a rough picture of the action that takes place when maroon is produced synthetically, said Mr. Greene. Precipitation of an organic dye on an organic base instead of on a mineral base was demonstrated to show how the ideal toluidine red pigment is made.

The chemical action of the mineral ultra-marine blue was made plain by exhibiting a bottle containing a dirty gray paste that resulted from mixing ground glass with lacquer and allowing it to stand overnight. A pair of panels painted with maroon in lacquer, one light and the other dark, indicated the two extremes of this color between which all shades can be used with entire success by the lacquer manufacturer despite the strong solvent action of the lacquer.

As for white and black, Mr. Green said that the only problem with white was to find a way to use white lead, which is very heavy and "livers" quickly in either varnish or lacquer, but no trouble is experienced with the blacks, which are nearly all of organic origin and light in weight.

ENGINE AND LUBRICATION PAPERS

New Design Burning Heavy Oil as Fuel and a Fresh Oil System Described

Radical departures from standard practice, along lines of application of known principles to secure improved performance, cannot fail to meet with general approval. This is

A. C. Attendu — Thomas E. Coleman — J. B. Fisher — Thomas S. Kemble

THE THREE AUTHORS OF THE TWO PAPERS PRESENTED AT THE ENGINE SESSION AND A PROMINENT FIGURE IN THE DISCUSSION AT THIS AND OTHER SESSIONS

true especially when such departures pass the theoretical stage and can be demonstrated as being advantageous, with new and radically different equipment or with equipment that has been modified or changed so as to produce desirable results in a new way. Therefore, the presentation at the Engine Session, held on Thursday morning, Jan. 28, of the paper by A. C. Attendu on the Attendu Heavy-Oil Engine and that on Relationships Between Lubricating Systems and Engine Performance, by T. E. Coleman and J. B. Fisher, was welcomed by the many members and guests of the Society who are especially interested in these subjects.

Since both these papers are printed in full elsewhere in this issue of THE JOURNAL, a brief resume of the substance of the two papers will suffice here and readers are referred to the printed text for complete details.

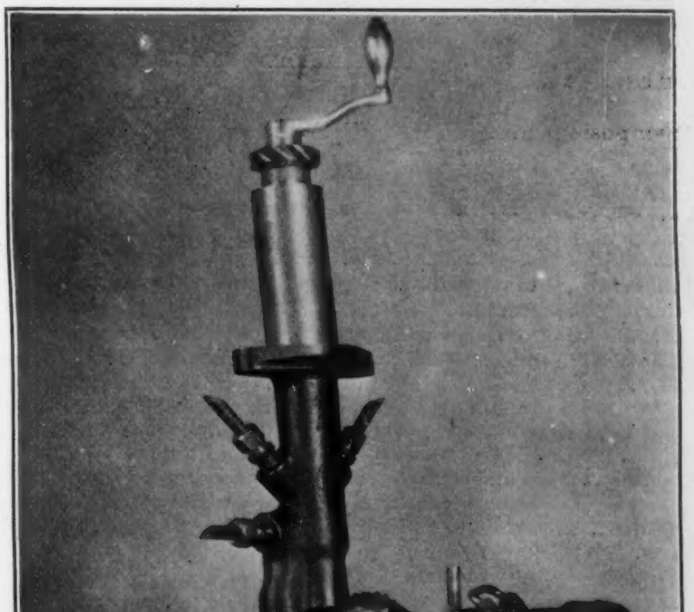
The oil-burning engine requires very accurate measurement of a small quantity of fuel for each stroke, which must be injected into each cylinder at the proper time; hence, the small-size, high-speed flexible heavy-oil engine is a difficult one to build. However, a four-cylinder two-cycle Attendu experimental engine having a 3½-in. bore and a 5½-in. stroke was built and was of the average power output used for automobiles. It developed 56 b.hp. at 1400 r.p.m. when running on 18 to 22-deg. Baumé fuel oil, with a fuel consumption of 0.76 lb. per b.hp.-hr., the maximum speed being 1800 r.p.m. and idling to 120 r.p.m., and had a weight of 17 lb. per hp. in running order.

Next, to determine whether an oil engine suitable for lighter-than-air craft, embodying all the features of the small Attendu four-cylinder engine, could be built and operated successfully at a weight of not more than 4 lb. per b.hp. a two-cylinder engine was built for the Navy Department, and is now undergoing tests. This engine actually develops 91 b.hp. at 1525 r.p.m. for a total weight of 417 lb., or 4.6 lb. per b.hp. After the alterations now being made are completed, the engine will develop about 116 b.hp. and have a weight of 3.6 lb. per b.hp. and the maximum speed will be 2200 r.p.m. The fuel consumption is actually 0.6 lb. per b.hp-hr., using 18 to 22 deg. Baumé fuel oil, and it is expected that this figure will be reduced to 9.5 lb. per b.hp-hr. and probably lower.

LUBRICATION AND ENGINE PERFORMANCE

The distinctive characteristics of various oiling systems, particularly from the standpoint of applying lubricant to the bearing-surfaces, were enumerated by Messrs. Coleman and Fisher in their paper, and those elements of engine performance which are affected by the type of oiling system were discussed. The major part of the data presented relates to the so-called "fresh-oil" system and to the "combined fresh-oil and recirculated-oil" system. Both systems are described and their effects on conventional engines are set forth in the paper, together with conclusions and observations that are based on laboratory tests and field experience during a period of 5 years on several engines having wide variations in design.

It was expected that J. G. Vincent would preside at this session but, as he was prevented from being present, L. M. Woolson, aeronautical and research engineer for the Packard Motor Car Co., acted as chairman. Following the presentation of the papers, Mr. Woolson expressed his regret at the



DEMONSTRATION MODEL OF FRESH-OIL SYSTEM LUBRICATOR
The Operation of This Equipment Can Be Demonstrated by Turning the Crank Shown at the Top. The Points of Departure from the Lubricator of the Pipes Carrying Oil to the Various Parts Are Evident

very limited amount of time remaining for a general discussion from the floor of the important points brought out in the papers. However, numerous written questions were submitted, and it is expected that these will be answered by the respective authors of the papers and printed in an early issue of THE JOURNAL.

POINTS BROUGHT OUT IN THE DISCUSSION

A few verbal questions were also asked and answered in the limited time allowed. With regard to the Attendu engine, one question brought the statement from Mr. Attendu that, in very cold weather, this engine starts more easily than does any gasoline engine of which he knows. With regard to the deposition of carbon, he said that the head is perfectly clean and that no carbon can be scraped off after a combustion temperature of from 1500 to 1600 deg. fahr. The power required to start this engine is from 1½ to 2 hp. He said also that an ordinary strainer such as is used on automobiles is used to keep the small fuel-jet clear.

Mr. Coleman replied to a question from H. A. Huebotter to the effect that the same grade of oil is used in the fresh-oil systems as is used ordinarily in other systems. Replying to J. W. Saffold, he said that no oil-filter is used in the fresh-oil system. The opinion was expressed by T. S. Kemble that the entire subject of successful lubrication of an internal-combustion engine hinges on the subject of the oil-seal. Asked whether different types of motor oil made appreciable differences in the efficacy of the fresh-oil systems, Mr. Coleman said that experiments have been made and that practically no differences could be noted. A lubricator of the type used by Messrs. Coleman and Fisher was exhibited, and explanations of its operation were made.

HEADLIGHTING THOROUGHLY CONSIDERED

Symposium Features Two Technical Papers and Numerous Prepared Discussions

A subject of vital importance, two splendid papers from experts, prepared discussion from other authorities, a large and enthusiastic audience, and an able chairman; these were the factors that made the Headlighting Symposium, held during the Annual Meeting, a memorable occasion. The Headlighting Symposium convened on the afternoon of Thursday, Jan. 28, 1926, at 2 o'clock. Chairman T. J. Lítle, Jr., spoke of the importance of the subject and differentiated between the illumination problem in buildings and plants that can be managed with a fair degree of ease, once the principles involved are understood, and the illumination problem as it presents itself to the automotive engineer who has to deal with something that is rolling around and changing position, with a consequent shifting of lamps.

In introducing the first speaker, L. C. Porter, commercial engineer of the Edison Lamp Works, General Electric Co., Chairman Lítle said that Mr. Porter had contacts which would enable him to give a view of the subject from the standpoint both of the producer and the user of the lamp and to discuss authoritatively the question of good and bad installations.

L. C. PORTER

G. F. PRIDEAUX

PORTER GIVES TEST RESULTS

Mr. Porter then presented the interesting material that had been prepared by himself and G. F. Prideaux of the same company. The complete paper is printed elsewhere in this issue of THE JOURNAL. The authors had planned and executed an extensive study of the subject of automobile headlighting, in an endeavor to clarify the technicalities by presenting them in the forms of photographs and simple charts, the chief object being to obtain data that emphasize the necessity of accurate control of the size and location of the light source with respect to the focal point of parabolic headlight reflectors.

An interesting feature in connection with Mr. Porter's presentation of his data was his use of two stereopticons at the same time. One lantern showed beams as they should be and one as they should not be. When the two pictures were seen side by side, a clearer conception could be gained of the large differences in the resultant beam of light produced by a very small displacement of the light source.

INTERESTING APPARATUS USED

Before making the tests that formed the subject of the paper, the authors constructed a device that enabled the lamp socket to be moved in any direction by micrometer screws having 32 threads per in., thus causing a one-half revolution of the screws to move the light source exactly 1/64 in., backlash being compensated by springs. A test reflector made as perfectly as possible was used in connection with the device. Three types of lamp were chosen to give beams of wide, medium and narrow spread.

Each set of illustrations showed the resultant beam when the light source was located at the exact focal point of the reflector and when it was moved, in one direction or another, 1/64, 2/64, 3/64, 4/64, and 5/64 in., away from the focal point. Slides were shown illustrating the effect when the light source was moved back of the focus, in front of the focus, vertically above, vertically below, sideways, behind the focus and to one side, and behind the focus and below it.

In summarizing the test-data presented, the speaker stated that the tests show the flux of light from an automobile head-lamp to be analogous to the possibilities of distribution of a gallon of water. The light can be concentrated into a narrow powerful beam, which corresponds to putting the water into a deep vessel of small diameter, or it can be spread out as if the water were poured into a large shallow pan. When light is taken from one point, it appears somewhere else. The area that the light is to illuminate and the intensity of light on that area are controllable as are the depth of water and the area it will cover. The control of the light depends upon accurately made equipment having light source, reflector and lens held rigidly in exactly the correct relation with one another.

The tests indicate that a precision of 2/64 in. in position of lamp filament with respect to the focal point of the reflector must be maintained to secure good all-round illumination. This is the problem not only of the manufacturers of lamp bulbs in producing filaments located more accurately with respect to the lamp bases but also the problem of lamp manufacturers in producing sockets, focusing devices and reflectors that will "stay put" within 2/64 in. The problem of the car builders is to mount the head-lamps accurately, and that of the manufacturers of lenses is to construct and maintain them so that they will produce accurate results. Mr. Porter pointed out that it will cost money to obtain these desirable results but he expressed the belief that the purchaser of a car would be perfectly willing to pay $5 more for a car if by so doing he could be assured of the added satisfaction that would be derived from head-lamp equipment properly made and accurately adjusted.

CARLSON REPORTS WASHINGTON EXPERIENCES

R. E. Carlson, of the Bureau of Standards, followed Mr. Porter on the program, presenting his prepared discussion of

the problem. His remarks dealing with the headlighting situation in the District of Columbia were substantially as follows:

Tests made in 1923 by the Bureau of Standards of headlights on some 400 cars indicated that approximately 73 per cent of the lights were out of focus, 46 per cent were improperly aimed and 54 per cent were considered to be glaring. The cars whose headlights were inspected were voluntarily driven to the Bureau in response to a public notice that tests were to be held. A reasonable assumption is that the condition of the equipment on these cars was better than on the average car inasmuch as the car-owners displayed sufficient interest to submit cars for test. Included in these tests were a number of new cars and a large proportion of these were found to have improperly adjusted headlights.

To secure reliable information concerning the practice of motor-car builders with respect to headlights, a letter was sent in August, 1923, to 51 companies. Thirty-four replies were received; nine companies did not answer and eight companies were out of business. The letter asked: (*a*) what the manufacturers were doing to insure correct headlight adjustment before cars were turned over to dealers or factory distributing branches, (*b*) what procedure was followed at distributing points to insure proper adjustment before the delivery of cars to buyers, (*c*) how service men and service departments of dealers adjust headlights, (*d*) what type of lens was being used on current models, and (*e*) what directions were given in the instruction book accompanying each car for headlight adjustment.

The replies indicated that five companies inspected the lamp equipment as it was received from lamp manufacturers to insure proper focus of the lamp filament in the reflector. Twenty-seven companies reported that head-lamps were adjusted at the factory, while in four cases adjustment was taken care of supposedly by branches and distributors.

With reference to the procedure by distributors, 15 replies stated definitely that distributors were supposed to check adjustment. Four manufacturers had no information about the adjustment after the cars left the factory, and the remainder of the 34 made no definite statement on this subject.

Relative to the adjustment of headlights by service men and dealers, 14 manufacturers gave special instructions to service men, and the remainder either did not give special instructions or had no information on the subject.

Concerning instructions in handbooks, 12 manufacturers had instructions in the handbook; 13 had no instructions; 2 issued special circulars, and the remainder had no information on the subject.

This survey seemed to indicate that a considerable gap exists between adjustment at the factory and the proper adjustment at the time the car is delivered to the user. Car builders generally, it would appear, have not done their part in pointing out the advantages of good lighting nor have they as a whole organized to give satisfactory service on headlights.

Mr. Carlson spoke of the creation of the office of Director of Traffic, in the District of Columbia, and the passage of regulations, effective last May, requiring the use of approved types of equipment. These regulations encourage the use of bright lights which must, however, be properly adjusted.

Educational Campaign Described

The speaker described an educational and adjustment campaign that, under his general direction, had been under way for some time prior to the going into effect of the new regulations, having the following aims: (*a*) provision of adequate facilities for headlight adjustment, (*b*) education of drivers as to advantages of good lights and encouraging the use of adjustment facilities and (*c*) education of enforcement officers and judges to obtain most effective cooperation in application of regulations.

One very interesting feature of the campaign was the use of a headlight tunnel by 13 agents of one large manufacturer, where for a period of 2 weeks free adjustment was given. Each agent was equipped with a tunnel made out of tar paper, about 6 ft. high and about 7 ft. wide, and about 20 ft. long. At the far end of that tunnel was placed an adjustment screen of white material, Beaver board being used in most cases. Car-owners of that particular make would drive up to the tunnel, have their headlights inspected and, if necessary, replacement of units made, and they were given a card indicating that they had had inspection made. This company was the first to start the adjustment campaign, and it served a very good purpose by stimulating other car dealers to follow suit.

The speaker pointed out that for a given period prior to the passage of the new regulations 57 per cent of the total accidents occurred at night, but that since that date only 23 per cent of total accidents have occurred at night. The Director of Traffic attributes this reduction in night accidents to the new headlight regulations and better understanding and use of headlights.

Crane Presents Safety Aspects

H. M. Crane, of the General Motors Corporation, was the speaker next introduced. He referred to a meeting of car engineers and the Headlight Steering Committee, held that same day, at which the question was brought up as to whether head-lamps should be considered from the point of view of safety or of comfort alone. The universal opinion by those best acquainted with the facts, said Mr. Crane, is that the head-lamp question is one of the very important safety questions. From the viewpoint of comfort, too, some action should be taken.

Mr. Crane spoke of the Steering Committee, under the auspices of the Illuminating Engineering Society and this Society, that has been formed to study the subject from the broad, general point of view of what is good light distribution. The first action taken by that Committee was the definite assertion that it had become desirable, due to experience from 5 years of use of present types of equipment, to permit or require the driver of a car to use a different system of light distribution when driving alone on the road than when meeting an opposing vehicle.

The speaker stated that the car company has not been properly instructing the owner with regard to the details of adjustment and operation needed to get the satisfactory result, and he pointed out several examples showing the effects of this practice. Mr. Porter's paper was mentioned as one of the finest pieces of work done toward breaking down this system of secrecy.

The need for discussion of the problem was emphasized, and the hope was expressed that from such discussion a great simplification of the method of head-lamp construction and

Demonstrators at Headlighting Session
R. W. Crary and Ben P. Wolf, President and Vice-President of the Nite-Eye Reflector Co., Waukesha, Wis., Who Showed a Test Board for Determining Light Distribution

maintenance would result. The need for cooperation was stressed.

Mr. Crane referred to the kind of equipment, giving controllable illumination, that is needed in headlighting tests, and said that R. N. Falge, of National Lamp Works, had with him some slides showing that type of equipment, which would unquestionably be of interest to those present.

Falge Shows Test Data

Mr. Falge's first slide showed a test car, with four head-lamps on the cross bar in front, arranged so as to be swiveled and tilted separately and also tilted as a unit. Another light down below may be added, if desired. The various units can be equipped with different types of lens, cut lenses and lenses with various spreads, and a single beam or road illumination built up from all four units, no one being the same as any other. Another slide showed a number of shields to be used over the different lenses, and other slides showed the sort of distribution to be obtained from the use of the shields. The method of using this test equipment was also discussed.

Mr. Falge believed that the data included in the paper by Messrs. Porter and Prideaux clearly showed that satisfactory results should not be expected from equipment that does not provide for the aiming of the beams. This he stated to be simple to accomplish as contrasted with focusing that is probably somewhat more difficult.

A table of test data, obtained when using three types of older equipment still in general use, was shown by Mr. Falge. The filament variations shown were somewhat less than those that are obtained in commercial lamps today, but, nevertheless serve to indicate that manufacturers with reasonable care might be able to produce equipment using these devices which would meet the American standard specifications with sockets fastened permanently in the reflectors and the adjustment procedure that of aiming only.

Continuing, Mr. Falge asked for consideration of several well-known principles of design and manufacture, which tend to maintain the optical accuracy of the various elements and to minimize the harmful effect on the beam of unavoidable commercial inaccuracies in the component parts of their assembly in head-lamps. He showed a table of figures to indicate that the types of equipment mentioned are reasonably sensitive to variations of the filament above and below the focal point. He mentioned, among other improvements, that of forming the upper part of the beam from the middle transverse zone of the head-lamp with a view to minimizing beam variations resulting from variations in filament positioning along the reflector axis. Another simple principle mentioned was that of bending the light rays from the extreme upper section of the reflector well down into the beam.

Mr. Falge directed attention to the fact that improvements are being made constantly by head-lamp and car manufacturers and concluded with the statement that the dual system of road lighting is rapidly gaining in favor among both car builders and technical organizations.

Commenting appreciatively upon the intensely valuable work that the Bureau of Standards is continually doing for the industry, Chairman Lítle introduced the next speaker E. C. Crittenden, of the Bureau of Standards, who gave a most interesting talk on Fundamental Principles of Headlighting and Glare.

Crittenden Talks of Fundamentals

Mentioning the fact that to talk in general terms about lighting effects is easy, the speaker said that the fundamental principles of lighting and vision can be stated very simply in qualitative terms, but that to give exact and correct quantitative values of the amount of light needed for vision is practically impossible because the eye is an organ of changing sensitivity. Continuing, he said that the only reasonable way to find out how much light is needed for a complex operation is to try that operation with different amounts and experiment until what seems to be satisfactory is found. This has been done at considerable length by various experimenters in the field of headlighting. No specific figures can be considered as having any very scientific basis; certain minimum and maximum values have been arrived at as representing, in the opinion of many people, limits beyond which no headlight should go; some other figures giving a consensus of opinion as to a light distribution that would be satisfactory to most drivers have been promulgated, as for example, by the Lighting Division of the Standards Committee.

For really satisfactory vision, the illumination should not be much below 1 foot-candle, said Mr. Crittenden, although a fraction of this amount may suffice when quick perception is not necessary. This would mean, for example, that if an object at a distance of 100 ft. is to be well illuminated, the candlepower of the source of light must be about 10,000, and, of course, for the same illumination at 200 ft. the candlepower would have to be 40,000. Good vision of objects at these distances would also require that the nearer foreground should not be illuminated to a much higher degree.

What Is Glare?

Relative to glare, the speaker said that this also is a thing which can hardly be stated in quantitative terms. After a brief discussion of glare in general, he raised the question whether it is possible to provide head-lamps that will light the road properly without throwing an excessive amount of light into the eyes of other drivers. He emphasized the point that the unavoidable condition to be met includes the problem of furnishing a large amount of light on the road and of projecting a small intensity at a small angle above the road at least at times when other cars are approaching. This necessarily calls for optical apparatus of good design and of accurate construction and a mechanical support for this apparatus that can be depended upon to keep it correctly aligned. As an example, the speaker pointed out that we would not expect William Tell to shoot the apple with a shotgun; no more can we expect to shoot light accurately where we want it without having precise and correctly aimed devices.

Responsibilities Definitely Placed

The responsibility of furnishing those devices, he continued, rests on the builders of automobiles. The responsibility of putting them in good condition rests with the dealer and the distributor, but the responsibility for keeping them in good condition must be divided between the service-station and the individual driver, and all must work together if good lighting conditions are expected to result.

In conclusion, Mr. Crittenden made the suggestion that in a study of lights the proper place to look is not at the lights themselves but at the road. Drivers, therefore, should watch the road and not the other man's lights.

Dill on Regulations

William L. Dill, motor-vehicle commissioner of the State of New Jersey, was the next speaker. Mr. Dill felt that much of the fault in the headlight situation is due to the manufacturer, who has apparently gone on the assumption that the man who could sell the devices cheapest was the man who would eventually get the business. With devices of this nature sold at an unbelievably cheap price, to expect the public who know nothing about the principles of illumination to answer to the authorities because their lamps are not in focus is impossible. Moreover, said Mr. Dill, little or no attempt has been made to send the automobiles out properly equipped and to impress upon those who come in close contact with the customer the necessity to impress upon the man who buys the car that it is just as essential that, while a sufficiency of light should be provided, that light should be directed where it properly belongs, as it is to explain to him how to manipulate his brakes and his gears.

The speaker believed that the crux of the problem is found in the statement that coordinated efforts in the solution of the head-lamp problem would tend toward a proper condition, namely, that the industry regulate itself rather than let a bad condition persist until law enactments are forced upon innocent people.

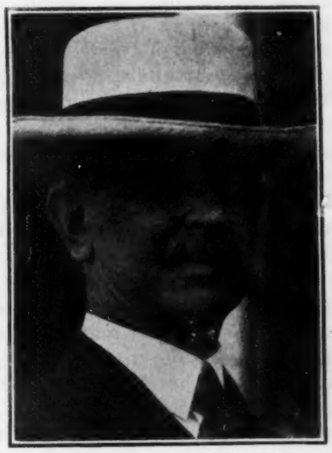
Cooperation of the Headlight Steering Committee with the Bureau of Standards and the Eastern Conference of Motor Vehicle Administrators was urged by Mr. Dill. The speaker also emphasized his belief that, except as a means of compelling the motorist to accept education on the subject, the enforcement of State laws is fruitless unless equipment is sufficiently well constructed to comply with the law respecting the head-lamps without requiring constant attention on the part of the driver.

At the close of Mr. Dill's remarks, upon a motion from Mr. Crane the audience gave a rising vote of thanks to Mr. Dill for the presentation of his most able talk.

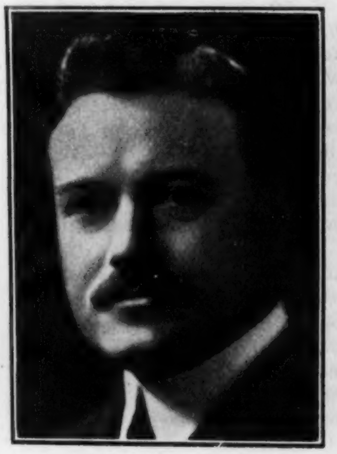
Sharp Recommends Intensive Study

Chairman Lítle next introduced Dr. C. H. Sharp, of the Electrical Testing Laboratories, who has, said Chairman Lítle, the happy faculty of combining a deep scientific mind with a practical application of the problem.

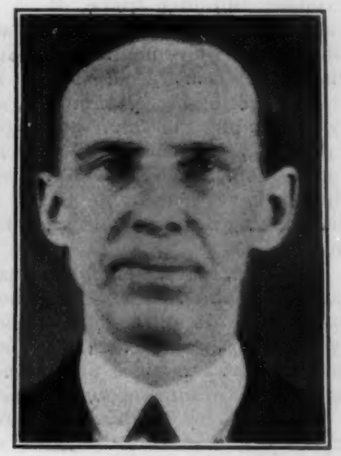
William L. Dill



C. H. Sharp



W. D'A. Ryan



E. C. Crittenden

Four Speakers Who Contributed Very Materially to the Success of the Headlighting Symposium

Dr. Sharp began his speech by referring to Mr. Dill's suggestion that the Headlight Steering Committee include representatives from the Bureau of Standards and from the Eastern Conference of Motor Vehicle Administrators; this matter, said Dr. Sharp, was taken care of when the Steering Committee was formed, and the Steering Committee includes representatives from the two organizations above mentioned and from the Hoover Conference on Street and Highway Safety.

After praising the work of the automotive engineers in developing a marvelous vehicle, Dr. Sharp pointed out that they had been so intent on making a machine that would run with tremendous acceleration, smoothness of action, quietness, speed, and economy that they overlooked certain features which are essential in the really perfect automobile. He cited brakes as an instance of tardy development and said that the matter of headlighting was a somewhat similar case.

Dr. Sharp spoke of the efforts made in the past to base specifications on the definition of adequate driving light that had been formulated by legislators, and welcomed the proposed research that will attempt to reach a better definition of a driving light and less glaring light, as well as to work out the proposition as it will appear when account is taken of the added factor that a disposition exists on the part of the administrators to permit the consideration of an alternative beam to be used in passing other cars.

Hunt Urges Need for Cooperation

J. H. Hunt, of the General Motors Corporation, expressed his appreciation of Commissioner Dill's remarks, saying that he would like to see copies of them sent to every general manager in the industry in sufficient quantity for the managers to pass them on to every individual in the organization who has anything to do with the headlighting problem. Such action, he felt, would tend to counteract the attitude on the part of some that it is not necessary to stir up the headlighting problem. He thanked Mr. Porter for presenting his data in such complete form, and emphasized the point made by Mr. Falge relative to testing under a variety of weather and other conditions; he also stressed the need for cooperation by all who are interested in the problem.

Remarking that engineering problems involve the combined use of science and horse sense, Mr. Hunt commented upon a disposition sometimes found in engineers to feel that when they use in some part of the problem the methods of the scientist, they have conducted a scientific test, although they have failed to analyze all of the factors and therefore get data that mean very little because the conditions were not properly controlled. As for the scientist approaching an engineering problem, he has frequently a disposition to feel that it is impossible to conduct a scientific test related to the problem because too many unknown or uncontrollable factors are involved, whereas the scientist likes to carry out his tests on the basis that he has only one variable and that it is accurately controlled.

Continuing, Mr. Hunt said that the fact that not all the factors are known or controllable does not justify taking data in a sloppy manner or saying that it is impracticable to use scientific methods. The best plan is to use scientific methods as far as possible and then use horse sense.

Horning Speaks of Test-Board

President Horning then spoke, stating that he was about to make a few remarks that had nothing to do with headlighting but considerable to do with common sense. Stressing the need for an open mind in approaching any problem, he traced out the course of development of any idea, discussing the following elements in the order given: research, invention, design, manufacture, use, standardization, and safety. Any problem is an overlapping of these elements.

The speaker then referred to a board designed for the testing of lights which would be exhibited and demonstrated at the close of the session. This board, he stated, will undoubtedly be the basis of the enforcement of law in the State of Wisconsin. The equipment consisted of a white screen with lights appearing at the points specified for maximum road-illumination, the glare point, a point 2 deg. below the point of maximum road-illumination and the point representing the location of a ditch. The lights were arranged so as to be visible to the driver only when the light cast on them by the head-lamp is less than the values specified in the regulations. The demonstration was viewed with great interest by those who attended the session.

Ryan on Light Characteristics

Walter D'Arcy Ryan, of the General Electric Co., presented his paper on Light Characteristics of Automobile

Headlights with Special Reference to Improved Distribution. It is planned to publish Mr. Ryan's paper in full in an early issue of THE JOURNAL. The paper was illustrated with slides that the author explained to an intensely interested audience.

The topics, range and glare, were discussed, and the statement brought out that, if headlights are adjusted for range, they glare, and, if adjusted for non-glare, they have no range. A series of tests was described that had been run on a number of the best types of approved headlight and lens in current use; as a result of these tests, the author reached the conclusion that, if we are to have range without glare, we must abandon the reflectors of the parabolic type or others of similar characteristics.

Attention was called to a tendency that has arisen in the last few years to produce a so-called hot-spot, that is, a small central area of very high candlepower for high-speed driving. The author believed, however, that unless this hot-spot is projected near the horizontal, where it would produce blinding glare, it is of no great value; and, if turned down so as to minimize the glare and come within the legal requirements, it produces a new source of dangerous glare from oil-polished or wet roads.

Relative to side illumination and depth of beam, desirability of having the main beam possess a good lateral spread so that it will cover not only the road but also the ditches for a considerable distance was emphasized. The beam should have reasonable depth so as to carry a gradually diminishing illumination well back to, say, within 20 ft. of the car.

The front of the machine, that is, the fenders, wheels and radiator, should receive sufficient light so that in case one light fails, an automobile cannot be mistaken for a motorcycle. Furthermore, this illumination, in conjunction with the light at the sides and immediately in front of the car, reduces, by simultaneous contrast, the glare effect.

The difficulty of driving in fog was discussed and it was stated that the remedy is to eliminate all high power reflected rays between the observer's point of vision and the distant point he is trying to see and at the same time to supply sufficient side and local illumination so that in the densest fog he will always know his exact position on the road.

DIMMING NOT APPROVED

Dimming was referred to as a most unsatisfactory and dangerous practice, and the author disapproved of manually operated tilting reflectors. The two-filament lamp, if put into use rapidly and extensively, would, he felt, do much to improve the situation. The headlights of the future, said Mr. Ryan, should have range without dangerous glare and should not require tilting, dimming or any other form of manual operation; but, until such units are widely in use, we should use every possible means to bring about the equipping of new headlights and those in service with any meritorious feature that will assist in taking the curse out of night driving. In conclusion Mr. Ryan stated certain specifications that he said must be met before an automobile headlight can take its place as a decided improvement over the existing equipment.

MOTORCOACH HEATING A REAL PROBLEM

Papers Cover Heating, Ventilating, Comfort and General Construction

At the Motorcoach Session held on Thursday evening, L. H. Palmer, of the Fifth Avenue Coach Co., acted as Chairman. The papers presented and the discussion thereon will be printed in full in an early issue of THE JOURNAL, but are abstracted herein for the immediate information of the members. In the absence of R. R. Fageol, Gordon Lee, vice-president of the Fageol Motors Co., presented Mr. Fageol's paper on the Modern Safety Motorcoach. The abstract of Mr. Fageol's paper follows.

Taking the experience of the railroads as a guide, the first requisite for the ultimate motorcoach was found to be ability to serve and attract patronage. The yardstick by which the equipment would succeed or fail would be its ability to sell rides, and the requirements for this passenger popularity were safety, comfort, convenience, and dependability, coupled with operating economy. The passenger automobile has fixed not only the riding habits of the public, but the rate of acceleration and speed, and any passenger-carrying vehicle that does not closely approximate those conditions must ultimately fail in the transportation field.

MECHANICAL IMPROVEMENTS EFFECTED

To lower the center of gravity, the wheels were spread farther apart than had previously been the practice, and a special frame with goose-necks over the front axles and kick-ups over the rear axles was constructed. Using axles 14 in. wider than the standard vehicle tread, the frame rails were spread as far apart as was practical to allow clearance for steering and brake-drums, and the springs were placed as far apart as was practical to eliminate side-sway. This type of construction, together with certain other structural features, enables a floor height of 24 in. to be obtained and at the same time the numerous advantages of easy riding and low tire expense afforded by the 36-in. tire are retained. In this way the center of gravity was lowered until the inter-city model could be tilted to an angle of 47 deg. before passing the ultimate point of stability.

Aided by the flexibility of the springs, the frame is designed to adapt itself to the road irregularities as this has been found to be a material help to easy riding. The cross-members are of channel construction, heavily gusseted and designed so the side-rails may twist slightly out of parallel as required. Since the frame design is not absolutely rigid, building the body to conform to the movement of the frame was necessary, and the body is therefore semi-flexible in the same direction as the frame.

The baggage problem is solved best by using a semi-head-room job that permits putting baggage on the roof more rapidly, and notwithstanding that carrying baggage on the roof has all the appearance and all the inconveniences of a make-shift or emergency arrangement, nevertheless no one has been able to offer a more satisfactory answer to this problem which is becoming more serious every day. If the motorcoach is to become a general transportation medium on runs up to 100 or 150 miles or more, to operate separate vehicles for the transporting of the baggage and general express between stations may eventually be found necessary.

The motorcoach represents one of the most difficult spring problems in the automotive industry, because of the great variations in both load factors and speeds. The ideal solution of these problems is a spring, the effect of which can be varied to suit the changing load and road conditions. To achieve entirely satisfactory results by the use of a so-called "two stage" or variable-load spring is not possible as yet. The lower or helper set of springs is made practically the same length as the main spring. To put the load on the tips of the helper springs and overcome the noise of intermittent contact between the tips of the helper and main springs, rubber blocks are mounted on top of the helper-spring ends. This construction permits the use of the helper-spring as a snubber for the main spring by connecting the two with steel loops.

The engine is so designed that it is made up of major assemblies, which are strictly interchangeable for ease and economical replacement of wearing parts. Later developments or improvements can be readily incorporated in older models. Sub-assemblies are interchangeable. The engine should, theoretically, never wear out if properly lubricated and maintained.

The cylinder-block is a separate casting. Cylinder bores, when properly lubricated, have a normal life of approximate-


Pierre Schon L. H. Palmer
A Leading Figure (Left) in the Discussion at the Motorcoach Session and, at the Right, the Chairman of This Session

ly 100,000 miles. The simplicity of the casting prevents warping and uneven expansion, which tends toward uniform wear and makes possible a low machining-cost with the resultant low replacement price, so that it is more advisable to buy a new block with the standard bore and standard pistons, than to regrind the old block and install oversize pistons.

How the Exhaust Is Handled

Gassing is in many localities proving to be a rather serious menace, and many interesting experiments to isolate the causes and cure them have been carried on. As it is obviously advantageous to mix the gases with the greatest possible volume of air at the earliest possible moment, the exhaust pipes terminate on the left hand side of the coach just ahead of the rear wheel, so as to take advantage of the rather compressed air condition along the side of the motorcoach. The rotation of the wheel also tends to mix the gases. Additional good results have been obtained by making a sort of ejector over the end of the tail pipe, the ejector tending to dilute the gases immediately after they leave the motorcoach. The rear end is the worst possible place to terminate the exhaust pipe, on account of the partial vacuum created by the moving vehicle, which causes the exhaust gases to cling to the rear of the motor coach and find their way in when it stops.

The development of satisfactory brakes has been one of the most difficult problems, and ultimately all motorcoaches will be equipped with power brakes, if this is not made compulsory in many places by special legislative action within the next 5 years. Owing to the apparent inability of controlling the consistency or coefficient of friction in fabric lining, a metal-to-metal type of brake has been developed. Experience has shown that high-carbon steel shoe-liners working against steel drum-liners have given best results, and with this type of material in most severe service, from 30,000 to 40,000 miles, or approximately 300,000 stops without relining, are secured.

To attract the maximum patronage, a motorcoach must be finished so that it can be kept clean at all times. The first Fageol coach, as well as every one since built, was finished in pyroxylin enamel, which is similar to the numerous celluloid-base finishes now being marketed under a number of trade names and coming to be used very extensively in the finishing of passenger automobiles.

Interesting Discussion of Fageol's Paper

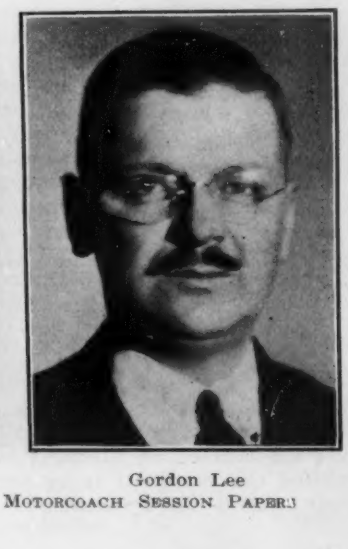
In the discussion of Mr. Fageol's paper, Mr. Lee, in answer to the question as to whether or not his company had experienced any difficulty with the squeaking of brakes when using a cast-iron shoe or drum, stated that such difficulty is encountered in the first few weeks of service, but because of a self-hardening surface that develops in this period of use, the noise ceases, reoccurring when this surface hardening wears off. This procedure is repeated continually.

A motorcoach operating-cost of 1 cent per seat per mile was reported by Pierre Schon who had in the last 2 years, been in charge of a fleet of over 100 motorcoaches and motor trucks covering an average of 75,000 miles a day. This mileage was largely on gravel roads. The actual cost, based on a very careful accounting system that gave the cost of operation per mile per vehicle each month, showed a cost slightly greater than 1 cent per seat per mile for the 7 to 12-passenger vehicles; a cost of 1 cent per seat per mile for 16 to 20-passenger vehicles and a cost of slightly less than 1 cent per seat per mile for motorcoaches seating from 20 to 24 passengers.

In answer to why the motorcoach builders had taken great trouble to design vehicles with narrow posts and wide windows and then proceeded to use curtains to obstruct the vision, Mr. Lee stated that the reason people like to ride in motorcoaches is that they have been educated to use automobiles and that by imitating the comfort and luxury of the passenger car, people use the motorcoach in preference to the electric and steam railways. For this reason his company saw fit to use silk curtains 10 in. wide sliding on rods so that they could be moved to keep the sun from bothering the passengers. Mr. Lee felt that the motorcoach industry has not reached the point where it could be shorn of details, such as silk curtains, looking glasses and velour carpets, as are necessary to invite patronage, but that when the motorcoach passes from the development to the strict utility stage, these details will be unnecessary.

In the discussion of gas leakage inside the motorcoach, Mr. Lee stated that this is a most difficult problem, his company having tried seamless tubing, jointed pipe and in fact practically every method of piping that could be utilized. With the present construction they have solved the problem of gas leakage, but only at a sacrifice of the efficiency of the heating system. However, sub-zero temperatures obtain for only about 2 weeks of the year and, consequently, a coach that has other points of superiority which will attract passengers is just as satisfactory to the operator as one that has a heating system which will keep the motorcoach warm in sub-zero weather.

With reference to the recent developments in the gasoline-electric motorcoach, Mr. Lee felt that this type of motorcoach will prove whether or not the elimination of the transmission gears is the forerunner of the ultimate type of motorcoach. Owing to the elimination of the gear transmission, Mr. Lee thought that the gasoline-electric drive would greatly increase the riding-comfort, but he did not know whether this would offset the increase, if any, in the maintenance costs of the gasoline-electric drive as compared with the gear transmission. Adopting the gasoline-electric motorcoach would give the electric railways, which

L. C. Josephs, Jr. Gordon Lee
Authors of Two of the Motorcoach Session Papers

have not looked with favor upon the motorcoach industry, an excuse to go into the business of operating motorcoaches because the gasoline-electric motorcoach can be considered as an electric vehicle, not as an automotive vehicle. He also mentioned that a saving in liability insurance of 25 per cent has been granted by the Underwriters because the gasoline-electric motorcoach has been classified as an electric vehicle.

With reference to body construction, Mr. Lee felt that without question, the use of all-metal bodies will be required of all motorcoach operators by future legislative action in the same way as steel cars are now required on railroads. He indicated also that the use of duralumin and aluminum alloys is being studied to a great extent and will doubtlessly be used extensively in the future.

Motorcoach Heating and Ventilating

The design and equipment for heating and ventilating motorcoaches, which is in use today, is not, according to L. C. Josephs, Jr., very different from that applied on the earliest types of motorcoach. The ventilating system applied to a motorcoach must be entirely unobstrusive. The amount of ventilation should be as great as allowed by the various other considerations. In a few places ordinances have been passed covering ventilation in public vehicles. The City of Chicago, for surface street car lines, requires 350 cu. ft. per hr. per passenger. However, this requirement is difficult to secure. This amount of ventilation is not impossible for a motorcoach when carrying its normal load, but if an additional load of 20 or 25 standing people is carried, to supply 350 cu. ft. of air per hr. per passenger becomes a real problem.

Certain natural forces can be counted on to cause a flow of air, such as difference in pressure between the front and rear end and the normal difference in pressure between the inside and outside produced by the motion of the motorcoach. The present system in use in most places consists in putting some suction ventilators on the roof and depending on window leakage and air from the doors when open to supply the intake. This is inadequate. Four ventilators mounted on the roof will exhaust about 7200 cu. ft. per hr. at 20 m.p.h., provided no restriction in the intake is present, but if the doors and windows are kept closed and reasonably tight the air exhausted by the ventilators will fall to a very low figure. To provide additional means for getting air into the coach therefore becomes necessary. This can be done either by a cowl ventilator or similar means at the front end of the body or can be accomplished in connection with the heating system by using one of the types of heater where air is taken from the cooling fan inside the engine hood and forced into the coach body.

The commonly used method of heating is to utilize the heat from the exhaust. Sufficient heat is available in the exhaust to supply the system, but not all of this heat is available. The exhaust from the engine may be at a temperature of 1000 or 1100 deg. fahr., but a large percentage of this heat is lost in radiation from the exhaust-manifold and other piping before it can be conducted into the body. Actually, however, only a small portion of the heat in the exhaust can be used for heating, but if carefully conserved, this is sufficient to meet a large part of the requirements. Another method of heating that is used on passenger cars and can be adapted to some extent to motorcoaches is to take the air from the cooling fan which has been heated by passing through the radiator and carrying this back in a duct to the body.

Josephs' Paper Discussed

In the discussion of Mr. Josephs' paper, W. J. Mayer, of the E. G. Budd Mfg. Co., outlined experiments that he had made with some of the ventilators now on the market. He constructed an air-tight box in the top of which was placed the ventilator to be tested and in the side of which was placed an anemometer. A current of air with a velocity of about 25 m.p.h. was then directed against and across the box. Five different types of ventilator were tested in this way and only one was found to actually create a vacuum in the box, thus bearing out Mr. Josephs' statement that few of the ventilators on the market will work if the body is completely closed so that no positive inside pressure can exist. However, by putting a slight ridge around the ventilator it would operate with an air velocity of 25 m.p.h., although without this ridge, the ventilators would not work even if the air pressure was increased to 35 m.p.h. Mr. Mayer pointed out that this is an old principle which has been used in railway construction.

With reference to the disposition of exhaust gases. Mr. Josephs stated that the objection to discharging the exhaust gases at the side of the motorcoach is that in the summer time when the windows are open and the motorcoach is standing still, any excess oil in the exhaust gases will drift up the side of the motorcoach and into the windows. The best method is to diffuse the gas when exhausted and then, if it gets into the motorcoach in any way, it is not so objectionable.

A. G. Herreshoff asked if any estimate had been made as to the number of British thermal units per horsepower that could be obtained from the exhaust heating-system when operating under average conditions. Mr. Josephs stated that under any circumstances, sufficient heat could not be obtained from the exhaust to heat a motorcoach properly and that, consequently, heat must be obtained from more than one source; the reason for this condition being that while the loss in the exhaust is sufficient, even at idling engine speeds, to heat a motorcoach, only a very small percentage of the heat is available, probably not being more than 10 per cent.

Motorcoach Riding-Qualities

A. F. Masury, of the International Motor Co., presented a series of slides showing the application of rubber-insulating material for absorbing vibrations in motorcoaches at their source and of preventing their inter-action by adequate insulation. The applications of rubber-insulating material shown in the slides were between the head of the engine and the radiator, the frame and the cross-members holding the transmission-shaft brake, the cross-members supporting the engine and the frame, the springs and the frame, the gasoline tank and the cross-members, and the cross-members holding the transmission and the frame.

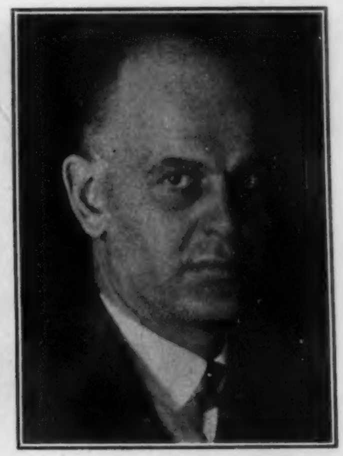
To determine the value of mounting units in this manner and also to obtain data as to the vibrations set up to the various units, a vibration-measuring device, known as a Newtometer, was developed. This machine is a high-period accelerometer that records the total change of acceleration to which the passenger is subjected. Curves made by this instrument were shown.

VAPOR COOLING OF AUTOMOBILE ENGINES

High-Temperature Effects and Cylinder-Temperature Control Explained

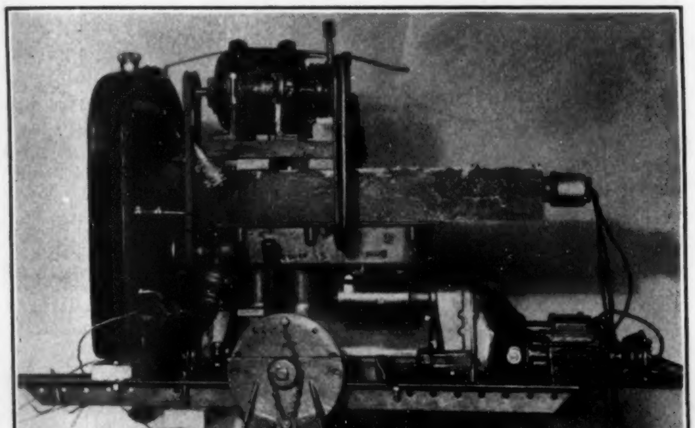
Conclusive evidence that improved methods of cooling automotive engines are being developed and practised, thereby prolonging the length of engine life and, consequently, the length of engine service, was afforded by the voluminous data presented in the two papers read at the Vapor-Cooling Session held on Friday morning, Jan. 29; and additional evidence of the compelling interest this subject holds for automotive engineers was proffered by the fact that 275 members and guests of the Society were present at this session. The papers were by Alex Taub and L. P. Saunders, on Effect of High Temperature of "Evaporation Cooling" on Engine and Car Functions; and by A. G. Herreshoff, on Cylinder-Temperature Control by Evaporation. The latter paper is printed in full elsewhere in this issue of The Journal and, for complete details, reference can be made to it. The other paper will, it is expected, be published in an early issue.



H. L. Horning Alex Taub L. P. Saunders A. G. Herreshoff
CHAIRMAN OF THE VAPOR COOLING SESSION AND THE THREE AUTHORS WHO PREPARED THE TWO PAPERS THAT WERE PRESENTED

Following the presentation of the paper by Messrs. Taub and Saunders, President H. L. Horning, who acted as chairman, remarked that he noted two significant things. First, with the "evaporation" cooling-system described, when the engine gets up to full load the exhaust-valve seats show much better cooling than with the ordinary water cooling-system. The figures presented show, he said, a very highly developed engineering approach to all the details of the subject of cooling an engine by evaporation. The exhaust-valve port and that portion around the spark-plug are the hot-spots in the cylinder and, therefore, the figures relating to differences in temperature are most indicative of what is happening. Second, he called attention to the decided difference in the fuel consumption at 10 m.p.h. between the so-called evaporation cooling-systems and the water cooling-systems. He held that the significant thing about the former system is that it does extremely well at low speed. He then called for discussion.

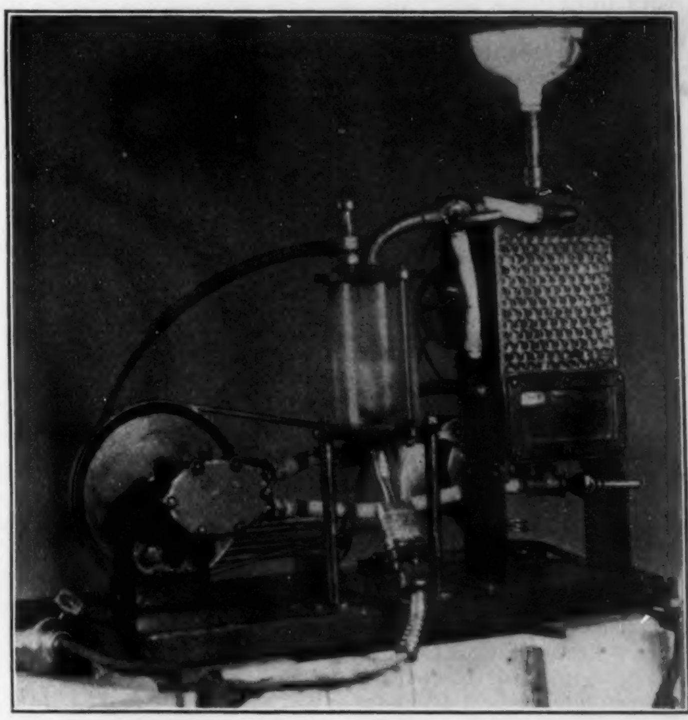


CLOSE-UP OF EVAPORATIVE COOLING-SYSTEM THAT WAS DEMONSTRATED BY L. P. SAUNDERS

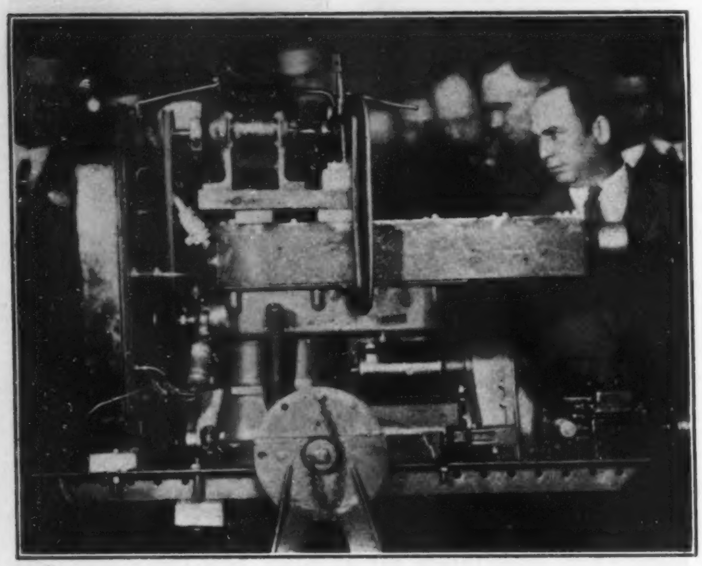
Replying to questions, Mr. Saunders said that the carbureter setting was determined by getting the maximum acceleration at 25 m.p.h. He answered a query from F. M. Young by saying that the narrower and higher the radiator is, the better it is. Further, he stated that the temperature of the water in the block with the pump high varies from 170 to 190 deg. fahr. and with the pump down low so that the water can drain into it, the water will have a temperature of from 215 to 220 deg. fahr.

Answering President-Elect T. J. Lítle, Jr., Mr. Saunders said that, comparing "ping" in the water-cooled and in the evaporation-cooled systems, this effect is a function of the particular engine on which the system is installed. If an engine does not ping badly, the same condition and the same water temperature are in effect with the evaporation cooling-system as with the water cooling-system. The worst condition for the evaporation cooling-system is with the water at 212 deg. fahr. in summer. If the compression pressure, the carbureter and everything else are set the same, Mr. Saunders stated that one will not get a worse condition at any time during the year. Regarding too high and too low a water level, he mentioned that if the constant-temperature cooling-system described in the paper is filled-up and operated as a water cooling-system and then stressed so as to boil the water, enough water will be forced out of an ordinary radiator to cause the system to change into being a condenser system. This occurs with too much water in the system. An insufficient quantity of water will cause the system to operate exactly the same as does a water cooling-system that has insufficient water.

C. B. Dicksee inquired as to the method of securing thermocouples to the cylinder-walls for the purpose of obtaining accurate temperatures, and Mr. Taub explained how carefully this was done so that external conditions could not



VAPOR-COOLING DEMONSTRATION APPARATUS
Shown by A. G. Herreshoff To Illustrate Action of Complete Vapor-Cooling System



MOTOR DRIVEN ENGINE
Equipped for Vapor-Cooling and Demonstrated by Taub and Saunders at the Vapor-Cooling Session

affect the readings, and how all wires and other parts concerned were insulated with tape and asbestos. W. W. Wells was told by Mr. Taub, regarding whether it had been found necessary to change the grade of oil or to change the oiling system, that this makes no difference so far as the bearings are concerned. The oil temperature rises with the temperature of the cooling medium; hence, an oil that will perform satisfactorily at those temperatures is all that is needed.

It was stated by T. S. Kemble that, in his belief, when applying the evaporation cooling-system to any specific engine, the engine must first be tried out to determine whether the water passages are such as to permit the free escape of steam; therefore, he advised caution regarding too great generalization on the basis of the sets of figures presented. In reply, Mr. Taub agreed and said that, to convert a given water cooling-system to a steam cooling-system, it is necessary to calibrate the water passages between the block and the head and determine the best condition, since each engine presents a separate problem. As to the provision of increased space at the top of the cylinder-head that would permit more violent agitation of the water than is possible with a more restricted cylinder-head, a possibility suggested by J. S. Erskine, it was said by Mr. Saunders that experiments along this line have indicated that this benefit can now be accomplished without having to provide a special head for the purpose.

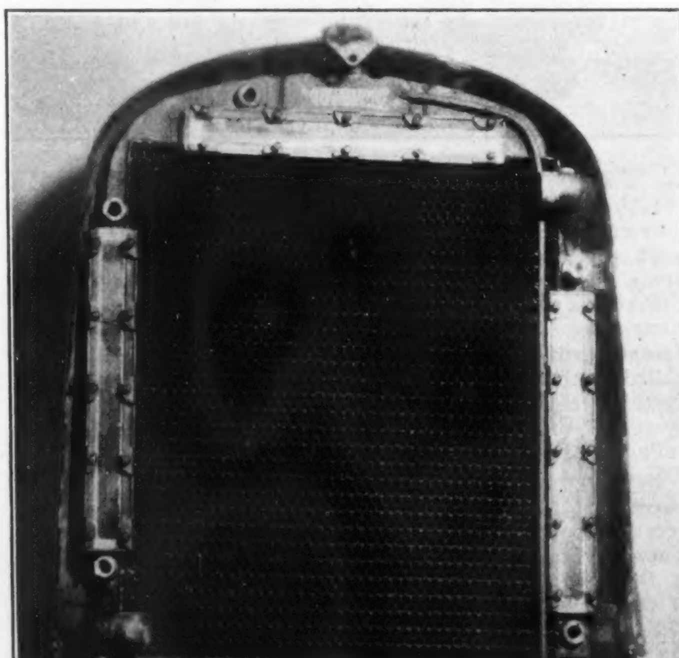
ACTION OF EVAPORATIVE COOLING-SYSTEM SHOWN ON SCREEN

An exceptionally interesting feature of the presentation of Mr. Herreshoff's paper was the projection on a screen, by stereopticon, of what actually takes place at the heated surface in the cooling-system he described. A hot-point element immersed in a water container placed in front of the stereopticon lens acted as the source of heat and as the heating of the water progressed from room temperature to boiling at 212 deg. fahr., all the effects, such as the formation of air bubbles, steam bubbles and convection currents, were visible on the screen and formed a vivid moving picture that was the subject of a running fire of questions from members of the audience and of comment and explanation by Mr. Herreshoff. He said that the rate of heat transfer of the standard hot-point heater used in the demonstration is about 2.5 B.t.u. per sq. in. per min., being about one-half the average rate of heat transfer in an internal-combustion engine working at full load or about the rate of an internal-combustion engine working at one-quarter load.

In the discussion that followed the completion of the delivery of Mr. Herreshoff's paper, the question whether it is necessary to use distilled water in the system in sections of the Country in which the water available contains lime or is alkaline was asked. Mr. Herreshoff replied that the quantity of such substances deposited is in proportion to the fresh water containing lime that is put into the system. If the system does not lose water, the new lime is not added and so will not accumulate in the system. G. A. Wahl stated that the first objection to the steam cooling-system usually heard from almost every engineer is that it is necessary to use a gear-pump or a plunger-pump. He asked if a centrifugal pump can be used. Mr. Herreshoff replied that a centrifugal pump can be used if the speed is constant, just as a centrifugal pump is used for feed-water supply in a large power house, but said that when the speed is variable the results obtained are very indefinite. However, H. L. Horning said that the centrifugal pump can be used and, in fact, actually is being used for this purpose at present. A question whether it is possible to obtain more heat from the jacket to heat the body of a car effectively by the steam cooling-system than by the exhaust system of heating was answered by Mr. Herreshoff to the effect that the former system mentioned is more effective. Mr. Horning supplemented this by saying that to his knowledge six motorcoaches now in operation are being heated satisfactorily by the steam heating-system that forms a part of the steam cooling-system, and that these engines are also being cooled perfectly by this means.

J. S. Erskine asked if any distinction is made between pump-circulating and thermosiphon-circulating systems. Referring to a previous statement made that the normal cylinder-block construction is used, he said the water passages between the cylinder and the cylinder-head are admittedly different in these two types of circulating system. The thermosiphon system is free, but the pump-circulating systems frequently are restricted to provide uniform distribution over the entire cylinder-block. To this Mr. Herreshoff replied that the statement referred particularly to the pump circulating-system; that is, the thermosiphon system has freer water spaces and greater volume in the water-jacket and more volume on account of the pipes being of larger size, so that it is even less likely to cause trouble.

Replying to a question from Mr. Saunders regarding



RADIATOR DESIGNED FOR VAPOR-COOLING
Shown by Alex Taub and L. P. Saunders in Connection with Their Paper at the Vapor-Cooling Session

whether it is possible to use the same size of radiator for the steam cooling-system as for the water cooling-system, Mr. Herreshoff said that a smaller radiator can be used with the steam cooling-system, because the efficiency of the radiator, besides depending upon the flow of air, depends also upon the temperature difference between the air and the metal surface of the radiator. If the metal surface of the radiator is maintained at a higher temperature, then more heat-units can be transferred by a given surface.

H. R. Cobleigh inquired whether experiments had been made for comparing the amount of carbon accumulation in steam cooling-systems and water cooling-systems. The reply to this from Mr. Herreshoff was that he had made no accurate comparisons, and Mr. Saunders replied that he had found, with an engine that was inclined to oil-up badly at

An Interesting Demonstration
Attracts Interest of Many at Vapor-Cooling Session

light loads, the spark-plugs do not become fouled when the steam-cooling system is used because the temperature is high enough to keep the oil dry. Mr. Horning stated that carbon accumulation is less when the steam cooling-system is used.

Asked by R. R. Mathews as to whether crankcase-oil dilution is eliminated or is merely kept to the minimum in the steam cooling-system, Mr. Herreshoff said that dilution is practically eliminated, it being possible to keep it down to 4 per cent.

Application of Steam-Cooling to Aircraft and Marine Engines

J. H. Geisse, of the Naval Aircraft Factory, made brief comments on late developments regarding the application of steam cooling-systems to aircraft engines. He said that recent tests have been made on a Liberty single-cylinder engine equipped with a steam cooling-system. He is interested in this system because the problems are different for aircraft engines than for engines that operate in a vehicle on the ground. He has found that the water cooling-system is not very far separated from the steam cooling-system, so far as the start of detonation is concerned. Some tests have shown the effect in this respect to be identical. In testing the thermosiphon system, it was found that the amount of circulation in the system had to be throttled to obtain the best results. With regard to the pressure system, increasing the pressure usually increases the tendency toward detonation. So far, zero pressure has been found to be best.

Regarding the effect the steam cooling-system would have on a marine type of engine, Mr. Herreshoff said that such an engine can be equipped to operate with a steam cooling-system very successfully. In that case the radiator or condenser could be the familiar water-cooled condenser used in steam vessels, and not an air-cooling type of condenser such as is used in automobiles. He stated also that the application of the steam cooling-system would be particularly advantageous in motorboats and would make possible the heating of the interior of the vessel by steam.

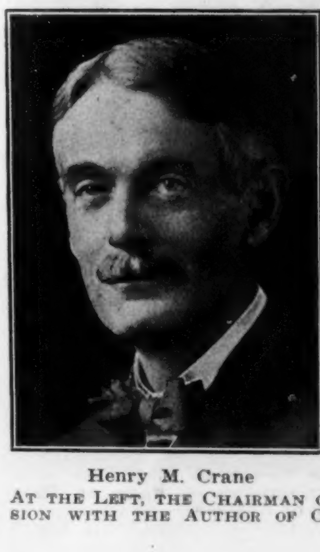
After the adjournment of the session, great interest was shown in the demonstrations that were made of the two types of steam cooling-system that are described in the papers presented. Working models of these systems were operated respectively by Messrs. Taub and Saunders and by Mr. Herreshoff, who were most courteous in answering in detail the many questions that were asked by the members who crowded around the apparatus. This of course aided very materially the successful conveyance of a thorough understanding of the principles involved in the subject of cooling an internal-combustion engine by evaporation and of their application and was greatly appreciated by those in attendance at this session.

PARADOXICAL REMEDY FOR OILING ILLS

Use of Pre-Diluted Oil Acclaimed—Cracked Gasoline Avoids Detonation

Prevention of crankcase oil-dilution troubles by the use of pre-diluted oil was the startling recommendation made at the Fuels and Lubrication Session on Friday afternoon by Robert E. Wilson, of the Standard Oil Co. of Indiana, who delivered extemporaneously the paper prepared by himself and Robert E. Wilkin, of the same company, and illustrated his talk with a number of lantern slides of charts showing changes of viscosity of oils in cars operated 500 miles. This paper, which was regarded as of great importance by a number of experts present, will be found in full in this issue of The Journal.

The proposal of the authors, that an oil suitably diluted to approximately the equilibrium value of the average dilution of oils in cars in operation be used, was said by Chairman Henry M. Crane to present one of the most interesting suggestions that had been made at any session on fuels held by the Society. H. C. Mougey, control chemist of the General Motors Corporation Research Laboratories, said that considerable work along this same line had been done at the General Motors Research Laboratories and that the results agreed very closely with those of Mr. Wilson. H. A. Schwager, consulting engineer, of Royal Oaks, Mich., said that with a steam-cooled car in winter operation adding 20 per cent of kerosene to medium lubricating oil overcame the starting difficulties and that even with hard service the bearings did not suffer as a result of the dilution of the oil. Neil MacCoull, research engineer of the Texas Co., told of dynamometer tests on lubrication with different oils and



Henry M. Crane

W. S. James

At the Left, the Chairman of the Fuels and Lubrication Session with the Author of One of the Papers at the Right

R. E. Wilson

R. E. Wilkin

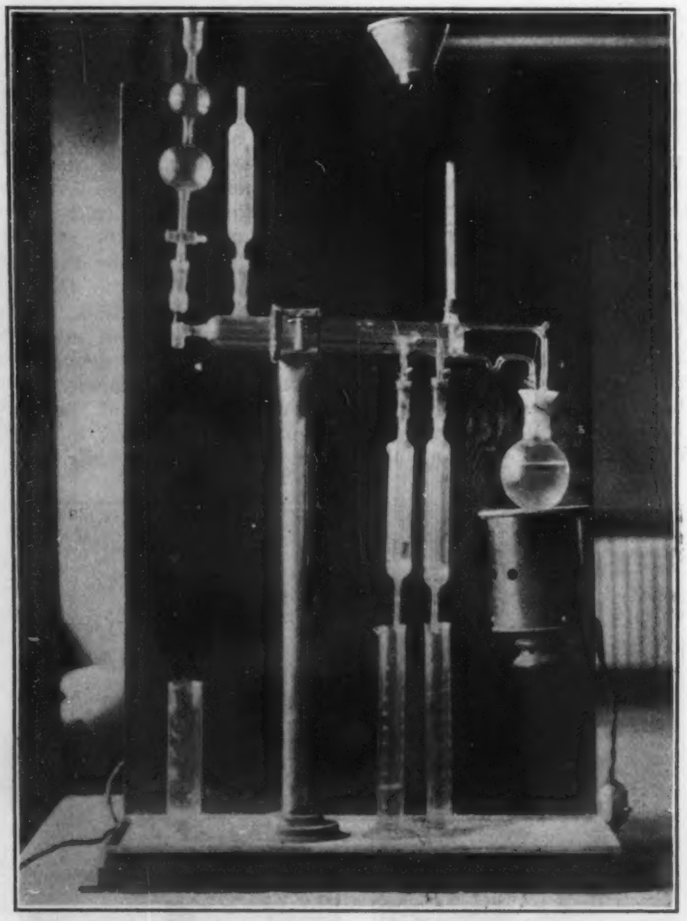
J. Bennett Hill

T. G. Delbridge

A Quartet of Authors Who Sang Two Duets at the Fuels and Lubrication Session

showed a number of slides of charts exhibited at the Spring Lake Meeting in the summer of 1924 to prove that, starting with oils of different viscosities, mixed with different percentages of diluent, all reached the same viscosity after a period of engine operation. He thoroughly believed that such a pre-diluted oil will help the conditions existing in a large number of cars on the road in which the designer did not provide for sufficient temperature or other means of reducing dilution to the point where it is perfectly safe.

T. S. Sligh, Jr., of the Bureau of Standards, observed that Mr. Wilson and his company were to be admired for their courage in proposing that crankcase oil-dilution be remedied by putting dilution in the oil, as the automotive industry had everything to gain by the use of equilibrium or pre-diluted oil whereas the oil companies had little to gain by the proposal. Last winter the members of the Bureau staff put lubricating oils diluted with gasoline in their cars to determine what would happen and their experience with this type of oil was wholly satisfactory and in every case one of the marked results noted was a decrease in oil consumption. He said he thought the pre-diluted oil deserves the hearty support of all automotive engineers.



Apparatus Shown by W. S. James

To Demonstrate His Contention that Fuel Tests Should Be Such as To Indicate the Principal Characteristics of Fuels as They Are Actually Used in Engines

Must Eliminate Water and Dirt

In the discussion the point was brought out that the "non-diluting" or pre-diluted oil guards only against reduction of viscosity of fresh oil and the troubles that result therefrom or from the use of too heavy an oil at the start. It has no effect on dilution with water or contamination by road dirt and metal particles, which should be excluded or removed by the use of air-cleaners, oil filters and water removers. Cost of the manufactured oil probably will be slightly more than that of medium oils, according to Mr. Wilson, because it is necessary to start with a considerably heavier base, but that is partly compensated for by the fact that the diluent is cheaper per gallon than the oil. On the other hand, the diluent must be closely fractionated to give the best results, hence the price of the prepared oil should be very similar to that of the present oils. So far as supply is concerned, tremendous quantities are available.

Kerosene will not serve anything like the same purpose as a diluent that the heavy ends of gasoline serve, he said, because, while it might be possible to operate at a high enough temperature to drive off an excess of the kerosene under certain operating-conditions, the volatility is not high enough to balance the high ends of gasoline and, if an equilibrium of dilution is to be maintained, something that is substantially the same or that has the same pressure relationship as the diluent that is in the engine must be put into the oil. Probably the pre-diluted oil would have a higher carbon-content than present oils, but the carbon deposition does not increase much in the engine when the prepared oil is used, as probably not so much oil gets above the piston-rings. If cars are fitted with air-cleaners, oil filters and water eliminating devices, said Mr. Wilson, no reason exists why the engine might not be run almost indefinitely on the oil, but, as a long time will elapse before a large proportion of cars are so equipped, he considered it advisable to continue to change the oil at 500-mile intervals to get rid of water and dirt contamination.

Mr. Winslow asserted that when an oil filter was interposed between the oil-pump and the bearings, no need to change the oil exists, and said that the disclosure by the oil companies that oil does not wear out and might be kept at a constant dilution percentage will probably cause a marked decline in the sale of oil.

Detonation Avoided with Cracked Fuels

Cracked gasoline may be the way out of detonation troubles with high-compression engines, according to J. B.

Hill, chief research engineer of the Atlantic Refining Co., who delivered a paper prepared by himself and T. G. Delbridge, of the same company. He said that cracked gasoline from present processes has been shown conclusively to be appreciably better from a detonation standpoint than uncracked gasoline from the same crude, the average cracked product at present being about similar to the higher-compression uncracked fuels and having a compression limit of approximately 85 or 90 lb. The petroleum industry is therefore looking at cracking as a possible means of producing fuels with a compression limit of 150 lb. and is undertaking extensive investigation to make this type of fuel by suitable cracking methods. This paper dealt with the problem of detonation as related to higher engine-compression and the use of fuels of the lower volatilities made necessary by the greatly increased demand for motor fuels.

Owing to the recent demand for greater engine efficiency and fuel economy, the demand for higher compression has been growing, said Dr. Hill, and several American cars are now being marketed with ratios of 5 to 1 and higher, but these higher compressions result in hard starting, rough running and other difficulties. These may be overcome and may lead to a maximum economical compression-ratio of as high as 7 to 1. The real difficulty in the way is the tendency of motor fuel to detonate. Evidence that marked improvement in avoiding this can be made along strictly mechanical lines is available but the main problem is the production of a fuel that will not detonate at the desired compression.

So far as known, every motor fuel will detonate at some maximum compression, but this maximum varies with the fuels, which can be graded at the compressions at which they will fire in the engine without detonation. A very close inter-relation of the automotive and petroleum industries exists in this matter and, until the producers of gasoline know what compressions the car builders want to use, the fuels probably will not be made more non-detonating than the cars on the road require, thus conserving the supply of high-compression fuel. On the other hand, engine builders will not put high-compression engines on the road until a satisfactory fuel for them is easily available.

While benzol apparently will withstand compression of 400 lb. and more without detonating, the quantity available is wholly inadequate and even when diluted with gasoline in large quantities the mixed fuel is insufficient. The same thing applies to alcohol. Anti-knock preparations, such as aniline and tetraethyl lead, are effective in raising the detonation point but there have been obstacles in the way of their use commercially. For these reasons the petroleum industry has devoted considerable research and production effort toward solution of the problem.

Uncracked and Cracked Fuels Differ

Paraffine hydrocarbons, which make up the basis of normal uncracked gasoline, show a tendency to detonate that increases with an increase of their boiling-point or molecular

Fred. J. Bolford James T. B. Bowles

Two Representatives of the Petroleum Industry at the Fuels and Lubrication Session

weight. To make motor fuels with a low boiling-point to permit of higher compression is possible but this would greatly reduce the total production. For example, a normal Mid-Continent crude capable of producing 27 per cent of present American consumption of motor gasoline without cracking would, if run for aviation gasoline, produce only 10 per cent of the latter.

Uncracked gasoline fractions from various crudes differ considerably in detonation point, and this variation is paralleled by a similar one in specific gravity at any definite boiling range. As a rule, the heavier the gravity the higher is the possible compression. Gasoline from Pennsylvania crude appears to be the poorest from the detonation standpoint, while gasoline from most California and Gulf Coast crudes is among the best. Average California crude appears to be equivalent in anti-knock characteristics to a blend of about 10 per cent of benzol and 90 per cent of average Mid-Continent gasoline. By segregating the gasoline from the crudes that are most non-detonating, a considerable production of a moderately high-compression fuel that will greatly decrease detonation troubles in present cars and partially satisfy the demand can be obtained. The compression limit of such a fuel will be about 85 or 90 lb.

Cracked gasoline seems to offer the way out of the difficulty of supplying a sufficiency of fuel that will not detonate at relatively high compression-pressures, and experience with the results of the cracking processes are of great interest, said Dr. Hill. The proportions of the various classes of compounds produced by cracking are dependent upon the conditions under which the cracking reaction proceeds; for example, higher temperatures tend to produce a greater proportion of naphthenic and aromatic compounds and, since both of these show non-detonating tendencies, to work out

F. C. Mock Ferdinand Jehle W. G. Wall Neil MacCoull

Four Members Who Attended the Fuels and Lubrication Session

the cracking conditions for their maximum production and to control the cracking reaction so that this maximum production would be obtained should be possible.

SOME NEW GASOLINE PRODUCTION FIGURES

Some very interesting gasoline production figures never before published were shown in a table thrown on the screen. These showed a total estimated production in 1925 of 10,700,000,000 gal. of gasoline and 90,000,000 gal. of benzol. Of the gasoline, about 2,000,000,000 gal., or 19 per cent, was uncracked fuel from California and Gulf Coast crudes and had an estimated compression limit of 85 lb. Uncracked gasoline from other crudes and natural gas totaled 5,200,000,000 gal., or 48 per cent, and had a compression limit of less than 70 lb. The remainder, 3,500,000,000 gal., or 33 per cent, was cracked gasoline of 85-lb. compression limit. Thus, 52 per cent of the total production would, if segregated from the other fuel, have a compression limit of about 85 lb. If a 10-per cent blend of benzol will allow 85-lb. compression, the 90,000,000 gal. of benzol would give an additional 8 per cent, making 60 per cent of the output in the high-compression class, said Dr. Hill.

The production of cracked gasoline is increasing much more rapidly than the total production, as was shown in curves from a lantern slide, and, while the production of benzol is almost negligible at present, it has been predicted that, with the development of the low-temperature carbonization of coal, practically all bituminous coal mined will be subjected to this process in the future. If only half of the total soft coal production of 500,000,000 tons were so treated, it would furnish 1,250,000,000 gal. of benzol, which would become a very important factor.

POSSIBILITIES OF VAPOR-PHASE PROCESS

Written discussion on Dr. Hill's paper, submitted by R. H. Sperry, consulting engineer, of Evanston, Ill., was read by Chairman Crane. In it the writer recalled that at the Service Engineering Meeting that was held in Chicago last November the point was brought out that a non-detonating fuel made by the vapor-phase process had been placed in the market. The long-standing question whether or not the organic paraffines that are available in large quantities can be converted commercially into the desirable series of non-detonating fuels has been solved, according to Mr. Sperry, by passing the paraffines over red-hot metallic oxides, which converts them into olefines and aromatics. If nascent hydrogen is introduced into the vapors, the naphthene series will be formed and the higher-boiling compounds will be broken down into low-boiling compounds, that is, heavy fuel-oils can be converted into motor fuel by this vapor-phase process.

Vapor-phase simply means that conversion requires only simple distillation at atmospheric pressure instead of the high pressures and high temperatures of the present cracking processes. The new method is not cracking but a chemical conversion by the oxidation of hydrogen. When completely converted, the fuel consists entirely of naphthenes, but, to produce a commercial fuel that will avoid changing carbureter adjustment, it is blended with 60 per cent of gasoline and forms a mixture that is non-detonating at compressions of more than 125 lb. The straight vapor-phase fuel is non-detonating at compressions of the order of 160 lb., Mr. Sperry stated, and when tested in a Packard engine was found to be equivalent to a 60-per cent benzol blend, no detonation occurring with a compression of 160 lb.

This process for changing the organic series and heavy oils into motor fuel presents a new principle by which naphthenes can be produced to sell at the same price as gasoline, or even lower. It offers a basic method for making motor fuel from practically waste products, if fuel oil can be so called, Mr. Sperry stated, and the results that have been obtained are worth the serious attention and cooperation of the automotive and petroleum industries.

Chairman Crane observed that the problems of starting and detonation had arisen since the war and that it is to be hoped that, as a result of the investigations, we shall arrive at a more uniform fuel in the various filling stations so that engine compression can be pushed up higher. Some high-compression engines work well with fuels in some parts of the Country but poorly in others. Many fleet operators can control their source of supply and other car-owners are willing to pay something extra for fuels of better anti-detonation characteristics than the usual supply, so it would be worthwhile for the oil companies to advertise and furnish such fuels.

Thomas Midgley, Jr., of the Ethyl Gasoline Corporation, pointed out that since Dr. Hill's paper was written the last commercial limitation on the use of gasoline containing tetraethyl lead had been lifted during the preceding week by the special committee appointed by the United States Surgeon General to investigate the effects of this anti-knock solution on the health of garage employes and others, but that restrictions are to be placed on the manufacture and mixing of the concentrated material as a safeguard. One advantage of the use of higher compression that was not sufficiently emphasized by Dr. Hill, he said, is that when the efficiency of the engine is increased by raising the compression and using a suitable fuel, the power output at any given torque is increased also by the amount of the increased efficiency, so that, by changing the rear-axle ratio to compensate for this increase in maximum power, a very decided increase throughout the normal driving range can be obtained in addition to the original increase.

If the engineer, when building engines, knew just what fuel mixture would be used in his product and just how much of hexane, oxygen and so on the fuel mixture would contain, he would have something definite on which to work, observed W. G. Wall, of Indianapolis, who said he wondered whether we would not eventually arrive at some exact mixture of hydrocarbons instead of taking them just as they come. To this Dr. Hill replied that it would be a big order to produce a gasoline of consistently the same admixture of the various compounds because gasoline, as produced today, is a mixture of a vast number of compounds, 1000 would be a conservative estimate, and to isolate them all and then blend them in the right proportions would be impossible. The petroleum industry, however, is working toward something that will give the same result, which is the production of a mixture having a definite standard volatility.

Answering questions, Dr. Hill stated that cracked gasoline is tending to produce a more-volatile fuel; that to color gasolines of certain characteristics in different ways so that the public could distinguish them is entirely possible, but that many fuels are now being colored and to have the colors standardized and controlled in some way would be necessary; also that the oil companies are working toward controlling the stability of the cracked fuels so that they will remain constant under long storage and are hoping, by controlling both temperature and pressure in the cracking process, to produce naphthenes, which are entirely stable.

CONTINUOUS-DISTILLATION TEST OF VOLATILITY

The general method now used to measure the volatility of a motor fuel is unsatisfactory because it is a batch distillation, whereas the fuels as used in carbureted engines are vaporized in the manifold and cylinders by continuous distillation, that is, fresh gasoline is supplied continuously as vaporization proceeds, said W. S. James, formerly of the Bureau of Standards but now assistant technologist of the Associated Oil Co., of San Francisco, in his address.

As a result of a limited amount of data obtained by tests of continuous distillation, he said that simple distillation methods for the laboratory testing of the volatility of gasoline should receive very serious consideration, and in his opinion the use of such a method would result in the development of a definition of gasoline volatility that would be more acceptable to both the user and producer than that now in vogue.

Until some years ago, petroleum products were produced by the batch-distillation method but, as that process is slow and expensive, gasoline is now removed from the crude or produced by cracking, continuous distillation and fractiona-

tion, and as a result the temperatures of production bear no rational relation to those of tests by batch distillation. Therefore it is not surprising that great difficulty is experienced in correlating the temperatures of tests with those of actual use.

In an endeavor to determine whether or not fuel volatility could be measured by continuous-distillation apparatus in the laboratory in which the temperatures of the test could be translated into those of production and use, simple apparatus illustrated by lantern slides and displayed for demonstration on a stand was constructed. The results of the continuous-distillation tests showed two marked differences from the usual batch-distillation method: (*a*) the temperature range is greatly reduced and (*b*) the per cent of bottoms shows approximately a linear relation with temperature. Practically nothing is vaporized below 160 deg. fahr. and all of the gasolines are completely vaporized at 320 deg. fahr. Various curves of the results of the tests were shown on the screen.

If this laboratory method of continuous distillation is truly representative of the process of vaporization that occurs in an engine, said Mr. James, translating the test temperatures into those of use should be possible if (*a*) the reduction of hydrocarbon vapor pressure due to the presence of air and (*b*) the effect of pressure on the temperatures of vaporization can be estimated. Since the results of tests show an approximately linear relation between temperature and per cent of bottoms, a fair assumption is that the temperatures of 50-per cent bottoms is the average boiling-point. The average molecular weight can then be estimated from the boiling-points of pure hydrocarbons.

HOW THE GROUP BONUS OPERATES

Lannen Cites Examples of Wage Incentives Applied to Non-Productive Labor

Stating that one of the principal aids toward cost reduction in manufacturing has been the application of wage incentives, Joseph Lannen, of the Paige-Detroit Motor Car Co., explained to those who attended the Production Session of the Annual Meeting how the group bonus has been applied in his plant to the so-called non-productive labor in the toolroom, maintenance and machine-repair departments.

The System

An order is first issued for each job. The work is then estimated, a copy of the estimate and the order number are forwarded to the time department and the order is transmitted to the department in which the work is to be done. The time is kept for each job and at the end of the pay-period, the actual and estimated time for all jobs completed in this period is totaled. If the actual time is less than the estimated time, this difference is prorated among the group as based upon their earnings during the pay-period. If the time taken to do the work is greater than the estimated time, the men are paid their day rate. If a job is cancelled, the original estimate is cancelled and an estimate of the actual number of hours applied to the job is substituted. At the end of each pay-period an estimate is submitted for the actual number of hours worked by each foreman who participates in the bonus. An estimate covering the actual number of extra hours allowed for overtime is forwarded to the time department at the end of the pay-period.


Joseph Lannen W. J. Mayer
AUTHORS OF THE TWO PRODUCTION SESSION PAPERS

Mr. Lannen stated that his shop began estimating the cost of tools in connection with work done in other tool shops and that it had been found possible to make these estimates accurate to within 10 per cent. This information, he said, was found to be very useful and valuable in checking the costs of outside work.

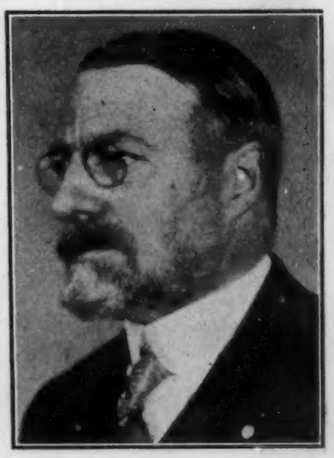
Interesting Results Obtained

After the estimater had become familiar with the work in the toolroom, the bonus system above mentioned was put into effect. During 20 months' operation the average bonus has been 6 per cent of the wage paid. The maximum amount received in any one pay-period was 27 per cent. During eight pay-periods no bonus was received.

Among the advantages claimed for this system by Mr. Lannen were the ability to predetermine the cost of building tools, the ability to schedule work properly and to make accurate promises as to the completion of a job, the possibility of determining the maximum number of toolmakers for a given amount of equipment, and the promotion of cooperation among toolmakers.

In discussing the application of the group bonus to the



L. Clayton Hill N. G. Shidle W. G. Careins W. W. Nichols
THE PRESIDING OFFICER AT THE PRODUCTION SESSION AND THREE OF THE DISCUSSERS


R. R. Keith H. D. Harrison
Two Who Attended the Production Session

maintenance division, Mr. Lannen stated that, during 4 months of operation, 74 men have earned an average bonus of 10 per cent of their wages. The maximum bonus received in a pay-period was 14 per cent and the minimum was 7 per cent. The machine repair department was said to have averaged 12 per cent with the maximum of 20 per cent and the minimum of 9 per cent.

In conclusion, Mr. Lannen stated that the measurement of the type of work described in his paper and the applying of wage incentives had to his knowledge never before been attempted. He felt that the results had amply justified the application of this system to the departments mentioned.

Lannen's Paper Discussed

In response to a question from W. W. Nichols, of D. P. Brown & Co., Mr. Lannen stated that accurate figures from the maintenance department are often very useful when the factory manager comes down to see if it is not possible to eliminate certain members of the department personnel.

Referring to the statement by R. R. Potter, of the Shakespeare Co., that the percentage of bonus workers mentioned by the speaker seemed considerably lower than the usual earnings in production work, Mr. Lannen stated that ordinarily a very low day-rate exists on production work and that the production man usually expects to obtain a good share of his wages through the bonus.

A question from W. W. Norton, of the Autocar Co., brought out the fact that an advantage of the group method over the individual bonus is the elimination of a great volume of bookkeeping.

Norman G. Shidle, of the Chilton-Class Journal Co., asked how the application of the group-bonus system to certain groups in the shop was received by other groups to which it had not been applied. Mr. Lannen replied that very little dissatisfaction had been caused and that in some cases it would be impractical to use the system.

In reply to a query Mr. Lannen stated that the application of the group bonus has in general tended to introduce a more stable element in various departments, thus reducing the labor turnover.

Among others who discussed Mr. Lannen's very able paper were R. L. Shepherd, of the C. B. Shepherd Co.; Charles M. Smillie, Jr., of the Ternstedt Co.; and Messrs. Metzler, Franklin, Williams, Strickland, Pughe and Loring.

Production of Steel Bodies

Following Mr. Lannen's paper, William J. Mayer, assistant engineer of the E. G. Budd Mfg. Co., showed a series of very interesting motion pictures that demonstrated the methods of producing steel bodies at his plant. It was interesting to learn that over 1,000,000 lb. of steel is used by this plant each day.

Among those who participated in the discussion of Mr. Mayer's remarks and asked questions concerning the processes that were shown by the motion pictures were D. E. Baskerville, of the Ferro Stamping & Mfg. Co.; W. G. Careins, of the Ajax Motors Co., and Charles M. Smillie, Jr., of the Ternstedt Co.

L. Clayton Hill, of Valentine & Co., acting as chairman of the session, functioned in his inimitably charming manner.


Ernest Wooler Vincent G. Apple
Two Members of the 1926 Sections Committee

SECTIONS COMMITTEE MEETS

Finances, Constitution and By-Laws, and Student Groups Among Matters Discussed

J. H. Hunt

The Sections Committee met at General Motors Building, Detroit, at noon on Jan. 27, 1926, Chairman J. H. Hunt presiding. The meeting was well attended, and several important matters were discussed.

Sections finances came up for discussion, and the sense of the meeting was that the budget system be continued and that special efforts be made to accomplish the purpose of the budget. Relative to the matter of administering the finances, the proposal was made that a certain sum of money be forwarded to each Section, to bring its bank balance to a certain pre-determined amount, and that this balance be brought up to this amount each month by a remittance from Society headquarters upon receipt of vouchers from the Sections showing the expenditures of the previous month. The amount of the balance would be determined for each Section separately, according to the needs of the various Sections.

The Committee took action on the matter of bringing the standard Section Constitution, By-Laws and Rules up-to-date. A proposed revision of the present Section Constitution had been the subject of a mail vote recently, and the opinions expressed in the mail vote came up for discussion and final action by the Committee. A draft of the Section Constitution will be made, incorporating the revisions suggested by the Committee, and this document will be submitted to all of the Sections at an early date.

The formation of student groups at colleges and universities was the next matter to come before the Committee. Announcement was made that a student group has been formed at Ohio State University, and it is expected that

NOMINEES FOR OFFICE IN TWO OF THE SECTIONS
O. W. Young, at the Left, Has Been Nominated for Chairman of the Chicago Section and Willard Newton, at the Right, Is the Candidate for the Secretaryship of the Cleveland Section

one will be formed at Massachusetts Institute of Technology in the near future.

Attention was directed to the matter of dinners and free entertainment furnished by the Sections on various occasions, and to the ruling of the Council that such expenditure must first receive the approval of the Council.

SOCIETY'S RESEARCH WORK REVIEWED

Cooperative Projects with Other Organizations Planned for Coming Year

During the Research Committee meeting, called together at noon on Friday, progress reports were made of the projects that were under way in the last year, and the lines of activity for the future were indicated. Dr. H. C. Dickinson, chairman of the Research Committee, presided over the discussion, calling on the various members for an expression of their views on the topics brought up.

To keep alive a sense of the purpose for which the Research Committee was formed, H. M. Crane outlined briefly its history, telling of the ideas that led to its inception and of the steps by which the Research Committee and the Research Department had developed their present functions and spheres of activity.

In connection with fuels research, W. S. James gave a talk on a proposed method for evaluating the volatility of gasoline which promised results of more value to both car designers and refiners. He pointed out that whereas motor fuels are vaporized in the engine by a continuous method of distillation, the vaporization characteristics are measured by batch distillation. A discussion was then had on further research into volatility tests designed to meet more exactly the needs of the industry.

R. E. Kohr told of the progress that has been made toward preparing for publication the results of the truck and tire impact-tests that have been made at the Bureau of Public Roads, under the joint auspices of the Bureau of Public Roads, the Rubber Association of America and the Society.

On the subject of riding-qualities research, Dr. Dickinson, chairman of the group particularly interested, described an instrument for use in measuring this factor of automobile use. The instrument is designed to give the total number of times the accelerations felt in the car exceed a certain set figure, and the total percentage of time the accelerations exceed that figure. C. M. Manly then spoke of the advisability of having an instrument that would tell the sequence in which accelerations of various values take place, as well as give a summary of accelerations of a particular magnitude.

O. M. Burkhardt, Research Manager, spoke of the latest developments in headlight research. He outlined what had been accomplished at the meeting on Jan. 28 of representatives of car builders with the Joint Steering Committee on Headlight Research. On this committee the Illuminating Engineering Society and this Society are equally represented. Mr. Burkhardt also reported on the conduct of the crankcase-oil contamination investigation. More than 60 service-stations, he said, had offered their cooperation, and the prospects were that a representative picture of the extent and nature of contamination under actual conditions of operation could be satisfactorily seen as a result of the survey.

SEVEN NATIONAL MEETINGS PLANNED

Summer Meeting Place and Other Live Topics Discussed by Meetings Committee

T. J. LITLE, JR.

The possibility of omitting some of the meetings of national scope previously held by the Society or combining certain meetings was taken up at the session of the Meetings Committee that was held at General Motors Building, Detroit, on Jan. 26, 1926. The decision was reached not to hold a national Motorboat Meeting this year, and to consider service matters in connection with the Automotive Transportation Meeting. The following national meetings are being scheduled for this year: Tractor Meeting, Summer Meeting, Aeronautic Meeting, Production Meeting, Automotive Transportation Meeting, Annual Dinner and Annual Meeting.

The Tractor Meeting will be held in Chicago, in cooperation with the American Society of Agricultural Engineers, March 25 and 26. Headquarters for the meeting have not yet been determined. The two sessions on the first day will be under the direction of the Society. Engineering and production will be discussed at the morning session; operation, at the afternoon session.

Lively interest centered around the choice of a place for holding the Summer Meeting. A mail vote recently taken of members of the Society showed that, of those voting, more wished to go to French Lick Springs, Ind.,

THE SUMMER MEETING

French Lick Springs, Ind. June 1, 2, 3 and 4

IMMEDIATELY FOLLOWING THE INDIANAPOLIS RACES

than to any of the other places considered. The Summer Meeting is to be staged at French Lick Springs; the event will take place during the same week as the Indianapolis Races, the dates being June 1 to 4.

The Aeronautic Meeting will be held at the time of the Pulitzer Air Races. This event will probably take place in Philadelphia at some time during the first 10 days of September.

An Automotive Transportation Meeting will be held again this year. A topic that has been mentioned to receive attention at this meeting is that of service and maintenance tools for fleet operation, and possibly also for passenger cars. The time and the place for this meeting have not yet been decided.

The Annual Dinner will as usual take place in New York City during the week of the Automobile Show.

Detroit will again be the scene of the Annual Meeting which will be held the week before the Chicago Automobile Show.

Considerable discussion was had relative to an appropriate time and place for the Production Meeting. No decision was reached, and it was decided that Chairman L. Clayton Hill of the Meetings Committee should arrange through Manager Warner of the Meetings Department to assemble a group of production men in the near future to discuss the matter.

Chairman Hill presided at the session which was well attended. The Meetings Committee will assemble again during the Summer Meeting.

Further announcements regarding the meetings will appear in THE JOURNAL each month.

CARNIVAL SATISFIES MULTITUDE

King Mirth and Queen Merriment Reigned Supreme at Oriole Terrace on Jan. 27

Some 1100 people set out to have a good time in Detroit on the evening of Wednesday, Jan. 27, 1926. Did they succeed? If they didn't, the Ananias-Munchausen Club recruited approximately 1100 new members that night, for to a man—aye, and to a woman too—they were vociferously unanimous in their verdict that the 1926 Carnival at Oriole Terrace, Detroit, was the best ever held.

Why shouldn't it be? It was engineered by engineers. Yes, and the way they moved around the dance floor, throughout the mystic midnight hours and into the early morning ones, gave new meaning to the term, automotive.

It was a festive scene and a mirthful crowd. Men and their lady friends in holiday spirit and gala attire; lights, many of them, not too bright and not too dim; tuneful songs and intriguing dances by entertainers easy to look upon; gay decorations of balloons and dolls and bright-colored streamers; an orchestra whose irresistible strains kept the traffic on the dance-floor at the saturation point whenever they played: these were some of the elements that made the evening of Jan. 27, 1926, an unforgettable event in the minds of those who were present.

Numerous felicitations to those fortunate enough to attend the 1926 Carnival and innumerable congratulations to the Carnival Committee whose efforts resulted in such a wonderful success!

MEMBERS HIGHLY PRAISED

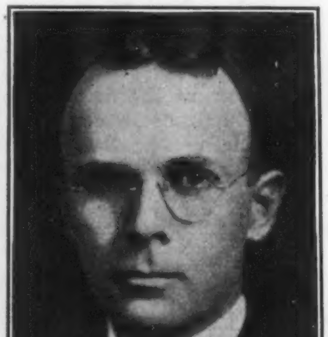
Committee Men, Chairmen, Speakers and Others Deserve Great Credit

Among mortals the matter of appreciation of duties well performed is often overlooked or unexpressed. It is certain, however, that no thinking person can believe that activities such as the Annual Meeting and the Carnival "just happen." Invariably a huge portion of unselfish effort must be devoted by loyal members of the Society or the undertaking is certain to fail. To express adequately the thanks of the Society to those who were responsible for the altogether happy outcome of the events of Annual Meeting Week would require volumes but it should suffice to mention in these columns the names of those who most actively participated in the technical sessions and in the general arrangements of the meeting and the Carnival.

AUTHORS AND SPEAKERS

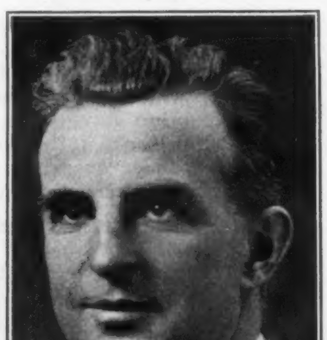
H. H. Allen	Gordon Lee
A. C. Attendu	Grover C. Loening
R. E. Carlson	A. F. Masury
T. E. Coleman	W. J. Mayer
H. M. Crane	S. A. Moss
E. C. Crittenden	H. F. Parker
T. G. Delbridge	D. M. Pierson
W. L. Dill	L. C. Porter
J. O. Eisinger	G. F. Prideaux
F. R. Fageol	W. D'A. Ryan
R. M. Falge	L. P. Saunders
J. B. Fisher	C. H. Sharp
C. A. Greene	T. S. Sligh
A. G. Herreshoff	C. R. Short
J. B. Hill	F. C. Stanley
J. H. Hunt	Alex Taub
C. W. Iseler	H. L. Towle
W. S. James	R. H. Upson
L. C. Josephs, Jr.	R. E. Wilson
Joseph Lannen	R. E. Wilkin

B. J. Lemon



Walter C. Keys

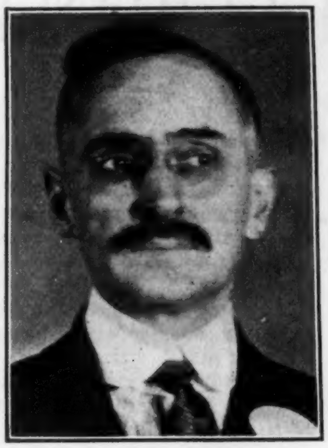
H. T. Ewald



Harlow N. Davock

FOUR MEMBERS OF THE CARNIVAL COMMITTEE

Frank K. Nutt



A. R. Nottingham

George Kubler

Walter S. Bennett

ANOTHER GROUP OF THOSE WHO ATTENDED THE ANNUAL MEETING

CHAIRMEN OF SESSIONS

Carl Breer	T. J. Lítle, Jr.
F. O. Clements	Arthur Nutt
H. M. Crane	L. H. Palmer
K. L. Herrmann	W. R. Strickland
L. Clayton Hill	E. P. Warner
H. L. Horning	L. M. Woolson

RECEPTION COMMITTEE

W. R. Strickland, *Chairman*

H. L. Brooke	H. A. Hansen
A. A. Bull	Phil N. Overman
C. Evans	H. M. Rugg

L. P. Saunders

CARNIVAL COMMITTEE

Walter Flannery, *Chairman*

H. G. Carron	L. Clayton Hill
F. A. Cornell	Walter C. Keys
M. Howard Cox	Harry H. Knepper
V. C. Cramer	B. J. Lemon
H. N. Davock	Neil McMillan, Jr.
H. T. Ewald	Mason P. Rumney

MEETINGS COMMITTEE

T. J. Lítle, Jr., *Chairman*

H. W. Asire	L. C ayton Hill
O. M. Burkhardt	G. W. Kerr
C. O. Guernsey	L. L. Roberts
A. W. Herrington	S. W. Sparrow
K. L. Herrmann	O. B. Zimmerman

P. G. Zimmermann

The Society expresses its appreciation to all others in addition to those above mentioned who assisted in any way toward the success of the Meeting.

The extreme generosity of General Motors Corporation in providing the meeting rooms, rent-free, was but another example of the attitude of helpfulness that has so often been exemplified by this organization.

OVER 20,000,000 MOTOR VEHICLES

THE annual statistical review of the automotive industry compiled by the B. F. Goodrich Rubber Co. gives a total for 1925 of 20,229,025 motor cars and trucks registered in the United States. This is an increase of 2,331,416, or 13 per cent, over 1924. It can safely be said that approximately 10 per cent of the Country's population became new motorists in 1925.

Increases in the number of cars in use were made in every State in the Union during 1925, except the District of Columbia, where the elimination of non-resident registrations was reflected. The industry produced and sold during the year approximately 4,200,000 cars and trucks. This is the greatest number of cars and trucks ever produced and sold in any one year. Today a motor vehicle is in use for every five people in the Country.

Six States now have over 1,000,000 cars registered. New York is still the leader with 1,637,670, a gain of 216,417 over 1924. California is in second place, with 1,443,985, a gain of 122,505. Pennsylvania passed Ohio and has taken third place with 1,367,092 cars and trucks registered. Ohio is fourth with 1,300,000; Illinois fifth with 1,267,400; and Michigan, the State passing the million-mark this year, shows a registration of 1,006,371. The combined registrations of these six States, which is 8,022,518, is greater than the registrations of the entire United States as recently as 1919. These six States have three times as many cars as are in operation in the remainder of the world excluding the United States.

The largest percentage gain in any State was made by Florida—49.1 per cent. Large increases were shown by other Southern States, Mississippi having a gain of 31.3 and Alabama 23.9 per cent. The smallest percentage gain was in Maryland, 3.7 per cent.

In the State of California 1 car is now registered for every 2.4 persons, and in Florida 1 for every 2.8 persons. The fewest cars per capita are found in Alabama, where 1 car for every 12 persons is the average. The general average throughout the Country, however, of 1 car for every 5 people signifies that this year the average will be one car for every family in the United States.

CAR MORTALITY

Deducting from the 4,200,000 new cars and trucks produced in 1925 the increase in registrations in that year, 2,331,416, the remainder, 1,868,584, gives the approximate number of cars that were discarded during 1925. This shows that the average life of a car is now somewhere between 7 and 8 years.

The automotive industry remains first in rank among all business enterprises, based on the value of its finished products, 90 per cent of the world's cars being built in the United States. In excise taxes alone this industry has paid $800,000,000 in the last 7 years.

VOCATIONAL GUIDANCE

IN some junior high-schools, seventh-grade boys are now given elementary exercises suggesting six groups of callings: for example, woodwork, printing, electricity, lathe work in iron, sheet-metal work, and automobile mechanics. These exercises are often taught by one teacher with six groups of five boys each, rotating among the several kinds of work through the year. The expression "general shop-work" has been used to describe such diversified tasks. In 1920 it would have been hard to find such a shop; in 1922 an investigator reported 569, and every indication points that the number is rapidly increasing. In other places, courses called "home mechanics" and "farm mechanics" are organized, offering diverse tasks in home repair and farm work of a constructive nature. What is sought is not technical skill but rather a certain versatility on an elementary level, a preliminary exploration of interests and abilities.

The problem of furnishing vocational contacts is so new that much research is needed. First, census data on occupations must be studied, to determine just what experiences should be offered. Second, research is needed to determine just what combinations of exercises are economically and educationally appropriate, and to draw plans for the best lay-out of shops and laboratories. Third, research is needed to plan more scientifically the steps taken by the pupils: from the industrial arts of the elementary school to a variety of contacts in the general shop; from these exercises in the general shop to more definite trial experiences in two or three callings; from these trials to enrollment in the vocational school. Fourth, it is necessary to work out the relationship of these trials to classes in occupational information and to such miscellaneous working experiences as will serve to test abilities and interests. Fifth, teaching methods must be scrutinized. Sixth, tests must be constructed and applied, both as teaching devices and as measures of progress. Finally, a checking up of the later experiences of individuals is needed to suggest further modifications in the aims and methods of the work.

Self-discovery through contacts with occupational tasks is but one side of the problem; the other is the discovery of the characteristics and opportunities of vocational life. Both go on simultaneously and form the foundation for reasoned choice of calling, and for subsequent training, progress and readjustment. Discovery of the vocational world is best facilitated by providing classes in occupational information, and the spread of these classes is the second great development since 1920.

Is there any logic in enrolling children in a given curriculum, particularly a vocational one that ordinarily closes the door of opportunity in all directions except toward the pursuit of a few highly specialized callings, without first making clear just what these callings are for which the curriculum prepares?

Many boys choose engineering because they wish an outdoor occupation, whereas 90 per cent of the engineers work indoors. An engineering professor, reporting a recent investigation, states that only 37.5 per cent of students entering upon engineering courses in American technical colleges and universities are graduated from these courses. He says:

> The decisions to study engineering seem to be based to a very considerable extent upon incomplete or unsubstantial knowledge. . . . Engineering education is consuming a portion of the lives of some 55,000 or 60,000 men per year . . . and it would seem that we should make every effort to have our work done for those who are able to profit by it in reasonable measure.

In 1920, classes in occupations were already well started in a number of American communities, besides which many attempts were being made to teach this information through classes in English and citizenship. Some mistakes were made at first. Methods have been gradually improved as teachers have seen that the best form of education is self-education. It is now understood that the main elements of occupational subject-matter are three in number: a study of the characteristics of a number of common occupations, a study of the general problems of the vocational world, and a study of education as related to work. Coincident with these improvements that have helped us approach to a worthwhile class, the work in the study of occupations has spread to thousands of communities in high schools and junior high schools, and has made a beginning in the colleges. Figures indicate that at least a quarter of a million children have studied occupations. The class is usually in the department of social studies, and is most frequently found in the ninth grade. It is often advantageously combined with classwork in educational guidance, which comprises such topics as how to study, the purposes of the various subjects, the characteristics of the several curricula, the educational opportunities of the community, and the like.

It is hard to see how even the ordinary workers of the future can understand their daily environment sufficiently to manage their relationships with each other and with employers in a manner safe for the general welfare, unless they are informed on such matters as the costs of distribution, overhead, wages, unemployment, capital, the business cycle, taxation, and the development and present status of the labor movement.

Shall we ever be able definitely to tell a young person what calling he is best fitted for? Professor James once remarked that whatever gains psychology might make, biographies were not likely to be written in advance. But a few of the present-day psychologists seem to envisage the time when, by compounding the probability coefficients for or against a proposed course of action, we may predict with reasonable certainty. Others maintain that the monitory attitude is the safer one to take, and that since the individual must live with, and take the consequence of, his decision, the responsibility for definite prediction is too serious for another person to assume.

In a democracy the distribution of persons among the 9000 or more different occupations must be made on the basis of consent. Our faith in life must extend to the assurance that at one and the same time the hopes and needs of the individual will be satisfied as he bends his energies to the task of satisfying the needs of his fellows. Vocational life is incurably cooperative. One's job is his way of seeking his own satisfactions by furnishing goods and services to his fellows.

Vocational guidance seeks to prolong the vocational infancy of the child. It counsels him to delay final choice of calling, and, after he has chosen, to continue his broad education as long as he can. It maintains, at the same time, that the policy is unwise which would carry the youth upon a high and rarified academic plateau, only to drop him into vocational life without any discussion of its problems. A pre-maturity safeguarded both from too early responsibility and from dangerous ignorance must in time be won for all.

Girls have a double vocational responsibility for which they must be prepared: first, the four-out-of-five probability of managing a home, and second, the likelihood, as represented by statistics of vocational life, of employment before, if not also during, married life.

Guidance must be really guidance, with the maximum of awakening and enlightenment, and the minimum of control and prescription.

Education for future occupational citizenship must compose differences and dissipate frictions commonly generated in working life. It aims to duplicate in modern life the intelligent harmony between employer and employed.—From an address by Prof. J. M. Brewer, before the Harvard Graduate School of Education.

AUTOMOTIVE RESEARCH

The Society's activities as well as research matters of general interest are presented in this section

DISCOVERIES AND RESEARCH

Benefits Derived from Pure Scientific Discoveries Through Cooperative Research

In a recent address before the American Society of Mechanical Engineers, Herbert Hoover, Secretary of Commerce, emphasized the need for greater financial support to pure-science research. He stated that:

> There is no price that the world could not afford to pay to men like Faraday who have the originality of mind to advance scientific thought great strides—and they wish no price. They need opportunity to live and work. No one can estimate the value to the world of an investigator like Faraday. Our whole banking community does not do the public service in a year that Faraday's discoveries do us daily.

In this address it is pointed out that we can claim no such rank in pure-science research as that which we enjoy in the field of industrial research. This contrast stimulates the question, What constitutes a desirable ratio in the efforts devoted to pure science and to industrial research?

Secretary Hoover finds that those engaged in pure-science research at our universities or upon their own resources probably do not exceed 5000, and most of these devote only part of their time to this work. And some men in our industrial laboratories are engaged in pure-science work. On the other hand, the scientifically trained personnel in applied-science investigation today is probably in excess of 30,000.

Considering that the need for systematic application of scientific knowledge is growing in incalculable proportions with every epoch-making discovery, it appears that the ratio of 1 to 6 represents a conservative proportion. This assumption implies that, if support is needed for pure-science research, proportionally greater attention must be given to industrial research. Various observations can be advanced in support of this contention. For instance, Mr. Baldwin, the British Prime Minister, is quoted as saying in a speech in the House of Commons:

> Until scientific methods and scientific men can take their place in industry, and an equal place with the administrator and the financier, British trade will never be strong enough or resilient enough to meet the shocks that it is bound to meet as the years go by, or to meet the sudden and unexpected changes that will always arise in international trade.

It is said that visitors from foreign countries have been impressed with the fact that scientific initiative is manifest only in some of our industries. That thousands of scientific men are necessary to make the discovery of one or a few great scientists useful and profitable to humanity through industry must be conceded. Great discoveries are the result of intuition and frequently also of perseverance and conviction. A great discovery may be compared to a foundation on which can be built an edifice or to an under-frame carrying a score or more of mechanical units that constitute a motor vehicle. However, the best foundation and the best under-frame do not of themselves render service; nor can they be of such benefit as can a complete edifice or a motor-vehicle.

We know that 2000 years elapsed after the observation that rubbed amber attracted light objects, before the first practical use of this electrical phenomenon was made. Moreover, some of the best products of great minds have suffered and even fallen into oblivion under the scorn of ignorance and because of lack of desire and enterprise for systematic application of scientific knowledge.

It is not only of vital importance that great discoveries be made but that many trained minds be prepared to accept and to utilize them, so that the public at large may enjoy them and may derive advantages from the great sources of power in nature.

From this it follows that the ratio of 1 scientist to 6 experts who apply science should increase in proportion as science is needed to take care of contingencies arising through the commercialization of inventions.

That epoch-making discoveries bring in their wake a need for intensive research is borne out by innumerable facts. The invention of the steam engine brought the discovery of the Bessemer and the open-hearth processes for the manufacture of steel in large quantity. Likewise, the invention of the internal-combustion engine will bring about the discovery of metals specifically lighter than steel yet with equal or better qualities. In the great cooperative enterprise we call civilization, a large number of well-trained specialists are needed for every man of Faraday's or Maxwell's caliber.

AUTOMOTIVE INDUSTRY AND RESEARCH

The ramifications of any branch of industry are many. No one would venture to say that at present science alone can be a panacea for trouble with any product that is used under adverse conditions by people who, as a rule, lack even the most rudimentary knowledge of the principles involved in its functioning. The fact that an intricate product such as a motor vehicle, although designed and built by a very able staff of engineers, will surely reveal weaknesses when it undergoes searching test in the experimental department, is well known. While customary failures should help in tracing mistakes, in interpretation they frequently make applied science appear obscure if not fictitious. A false doctrine masquerading as a scientific proposition may produce more harm than any belief of a clearly irrational character. The real cause for failures is nearly always improper correlation of effort, lack of facts or pseudo-science. It is often overlooked that a motor vehicle is not the product of a single mind or organization but a development of cooperation of automotive engineers with electrical, civil, illuminating, and production engineers, and with chemists, metallurgists, mathematicians and physicists.

After a motor vehicle has gone through the experimental stage, it is necessary, in order to compete, to produce it at an attractive price. To do this the vehicle has to be produced in large quantities. Further, to facilitate production in large quantities, it is necessary to provide an elaborate plant layout, jigs, fixtures, and inspection gages. It is not within the province of this article to discuss production problems. They are well known. Suffice it to say that elaborate production and inspection equipment imposes innumerable restrictions on designers when an emergency change in design is required.

It is obvious that under such conditions a designer has to make the best of the situation rather than insist on lengthy scientific deliberations. To salvage existing parts rather than to design a new unit that would conform nearer to the dictates of the latest experience is often expedient. These facts are enumerated to emphasize the importance of exercising extreme precaution in the design of new models.

There has been latterly considerable evidence that some precaution is exercised in bringing out new models. For instance, if a model has proved relatively successful it is, as a rule, extensively copied even by competitive producers. This practice, while by no means commendable, may be character-

ized as a crude form of cooperative research. It is crude insofar as one party is made to carry the entire burden of the development work. There can be no doubt, however, that one manufacturer can learn considerable from the other. This hardly needs to be substantiated. Frank discussions of common problems always yield much food for thought.

The next logical step is naturally to carry out joint researches. The reasons that this should be done on a far more extensive scale in the future are numerous. It is well known that correlation of effort eliminates waste that would otherwise result from mistakes or duplication. Pooling of knowledge and resources is carried much further in other branches of industry than in research. For instance, a cross-licensing patent agreement was instituted by the National Automobile Chamber of Commerce some 11 years ago and renewed in modified form about 1 year ago. It is conceded that incalculable benefits have been derived from this, even though a patent is generally distinctly recognized as the possession of an individual or an organization. It is different with pure scientific knowledge or research results. These are so interwoven that only joint efforts and corroboration of results can lead to reliable data; and anything short of accurate data is worse than useless, for it breeds contempt when applied.

This Society provides the logical meeting-place of scientists and engineers for the purpose of advancing the arts and sciences involved in the design and production of the units that constitute automotive apparatus. It is one of the Research Department's objectives to stimulate joint research on problems that are expected to become urgent in the progress of the industry.

There are at present in progress cooperative researches on six major projects, namely, fuel, lubricants, highways, headlights, riding-qualities, and gears. While satisfactory progress is being made with all of the projects, a more general interest would be most welcome. This cooperative research should prove of greatest benefit to smaller manufacturers who have not the staff or the equipment to carry on more than routine tests. It is, however, surprising to note that the largest and the best equipped manufacturers take by far the most interest in this cooperative work. Of course, important reasons why all should be equally represented exist. Without the whole-hearted participation of all the results will not be the best. It would, for instance, be unsatisfactory if a few only should specify an ideal headlight. For this and many other reasons, it is not only necessary that an organization exist through which cooperative research can be carried on but that all who are eligible should participate in the joint efforts to the limit of their ability.

REMARKS OF A VISITOR

In the summer of 1925, Ernst Neuberg, director der Deutschen Automobil-Constructionsgesellschaft m.b.H., Berlin, visited several leading motor-car manufacturing plants in this Country. On request, Mr. Neuberg sent to this office a copy of a paper giving his observations. He emphasizes that the main reasons for the popularity of the passenger car in this Country are to be found in the admirable financial circumstances of the American workmen and in the fact that Americans, in general, do not object to driving cars themselves, with such attendant duties as this may incur.

Mr. Neuberg says that while America has a much greater market for and is far ahead in the production of passenger cars, this cannot be said in regard to motor trucks and tractors. He asserts that several German firms can compete in design, construction and price of the latter.

ANTI-FREEZING SOLUTIONS

Various inquiries have been received at the Society's Research Department pertaining to anti-freezing solutions. Constantly recurring interest exists in various compounds at this season. For this reason, attention is called to a report of a Committee on Anti-Freezing Solutions, published in THE JOURNAL of November, 1921, p. 307. In this the requirements of anti-freezing compounds are enumerated and a table of freezing-points and gravities of alcohol and glycerine solutions are included.

Since this report was made it has been found that during the winter of 1924-25 considerable quantities of magnesium-chloride solutions were sold for use in radiators. It has been pointed out by the Bureau of Standards that these solutions are more corrosive than calcium chloride. No effective means of retarding their corrosive action by the addition of a second salt has so far been found or has been brought to the attention of the Bureau. The maximum protection that magnesium chloride gives is that it will prevent freezing only above —28 deg. fahr.

HIGHWAY RESEARCH

The Highways Committee of the Society has been cooperating jointly with the Rubber Association of America, with the Bureau of Public Roads on motor-truck tire-impact forces. For the measurement of these impact forces the Bureau of Public Roads has experimented with beam coil-spring and sylphon accelerometers, as well as with a Krueger cell. A short description of this experimental work and of calibration methods for quantity tests are given in the December, 1924, issue of *Public Roads*. Following this preliminary work the Bureau has carried out with a calibrated coil-spring accelerometer a large number of tests with solid and cushion tires.

At a meeting held in the City of Washington last October, the Bureau submitted a report covering the tests. This was discussed at length. Thorough discussion of the entire subject and some further checking of particulars was desired prior to rendering a formal report to the automotive industry.

In connection with this work the following expressions of Charles M. Upham, director of the Highway Board of the National Research Council, are of interest.

> In the development of every science certain periods stand out as epochs in the progress of that science. Just as the Bates Road; the Pittsburg, Cal.; and the Arlington tests were distinct developments in the science of highway construction, the investigations financed by industrial interests and conducted under the auspices of the Highway Board of the National Research Council mark a new era in highway research. Several of these studies are now under way, and in every case they are concerned with a moot problem in highway work which no State highway department or industrial organization would ordinarily conduct alone.
>
> The first study was that of the economic value of steel reinforcement in concrete roads. Careful field inspections have been made in every section of the Country and information is now available that covers all conditions of service. It is expected that as a result of this investigation, the matter of reinforcement in concrete roads will no longer be a moot question.
>
> Another investigation of utmost importance relates to the development of earth roads. The object is to determine some type of road surface that will be low in first cost and maintenance and suitable for light traffic.
>
> Much interest has been shown by engineers in the culvert pipe investigation. It is hoped to determine the proper basis of comparison for evaluating the life, usefulness and economic value of different types of culvert and small drainage structure in use, thus obviating the uncertainty that now exists.
>
> Another important development in the last year has been the summarization of highway research progress that is being made by the Bureau of Public Roads and is appearing in *Public Roads*, the research journal issued by that organization.

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Metalclad Rigid Airship Development

By RALPH H. UPSON[1]

ANNUAL MEETING PAPER *Illustrated with* PHOTOGRAPHS, DRAWINGS AND CHARTS

ABSTRACT

SEVERAL years ago some of the most prominent leaders in automotive industries cooperated to form a purely engineering group that had as its primary purpose developing a type of rigid-airship construction in which the public would have confidence. It was conceived that such an airship should be

(1) Fireproof
(2) Weatherproof
(3) Durable and permanent in structure
(4) Navigable in practically all kinds of weather
(5) Economical in the use of buoyant gas and ballast

To meet all of these requirements it was decided, after mature consideration, that a substantially all-metal construction was imperative. Development of the Metalclad airship has now reached a point where the general soundness of the design seems fully assured as

(1) The structural and aerodynamic efficiencies have been established by both analytical and experimental methods
(2) The technical problems involved in the construction have been mastered to a certainty hitherto unapproached in any new design
(3) The general design of an airship of demonstration size, 200,000 cu. ft. or one-tenth the size of the Shenandoah has been completed
(4) Full-sized structural members of every part of the framework have been built and tested to destruction revealing that the minimum safety factor is double that of the Shenandoah. The longitudinal strength of the metal hull will be more than four times as great as that of the Shenandoah
(5) The problem of riveting the metal hull-plating has been solved through the perfection of an automatic riveting-machine
(6) The problem of making the metal hull gas-tight has been solved with surprising efficiency indicating an osmosis of about one-tenth that through gold-beaters skin and only one-hundredth that through rubberized fabric
(7) A suitable coating to prevent corrosion has been satisfactorily tested
(8) A source of supply of aluminum alloys of dependable quality is assured
(9) Shop facilities for fabrication are available in Detroit
(10) Skilled metal-workers familiar with aluminum and its alloys are at hand

These results depend upon certain fundamental principles that are described in the paper. In effect, the design is an entirely new one, but adheres to the fundamental unalterable principles underlying all sound engineering-work.

The paper states that the Metalclad airship is the last step in the development of rigid airships and most certainly must be adopted if such a means of transportation is to be made available both for the arms of National Defense and for commercial purposes.

Appendices that include extracts from studies and texts arranged to illustrate the subject matter in the main paper and furnish food for discussion supplement the paper. This material is partially elementary in form as limitations of space preclude any attempt at completeness.

A YEAR and a half ago the airship Shenandoah, which is shown in Fig. 1, made history in its celebrated cruise of 8000 miles from Lakehurst to the Pacific Coast and return. The ship encountered nearly every kind of weather on this trip, only to be destroyed later by a rather ordinary type of storm on a comparatively short trip. Shortly after the Shenandoah's great cruise the Los Angeles came over from Germany without a stop, covering an average distance of about 1500 miles per day, compared to about 150 miles per day averaged by the "Around-the-World" airplanes. In addition, an airship like the Los Angeles has facilities for the utmost convenience and comfort of passengers, and its fuel consumption is only a small fraction of what is necessary by airplane per ton carried; yet it is commonly admitted that even the Los Angeles is not, in any sense, an economical vehicle for practical commercial transportation.

What is the reason? Theoretical considerations, even beyond actual performance, show that airships have fundamental characteristics of vital importance for commercial as well as military use. But we are coming to realize, with the force of conviction, that even such fundamental advantages as speed, carrying capacity, low fuel-consumption, and the practical elimination of right-of-way, can be easily offset by what at first sight might appear to be mere incidentals. Initial cost, rapid depreciation, inflammability of the fabric, complications of helium, insufficient strength, poor stability and control, cost of large sheds, and difficulty of mooring and housing are the items that spoil the picture and do away with most of the advantage which is otherwise gained, from a commercial viewpoint.

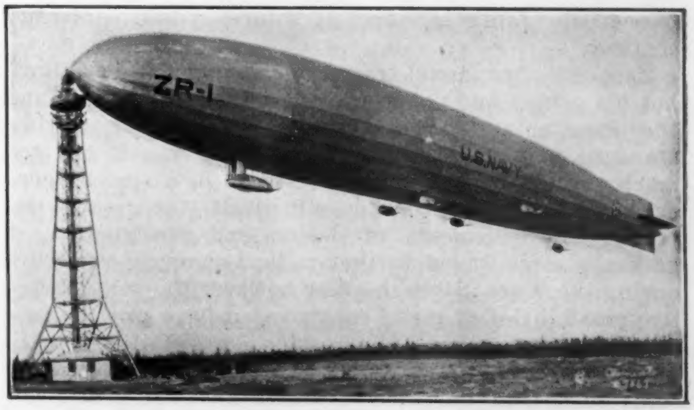


FIG. 1—THE SHENANDOAH AT ITS MOORING MAST
This View Was Taken at the Naval Air Station at Lakehurst, N. J.

[1] M.S.A.E.—Chief engineer, Aircraft Development Corporation, Detroit.

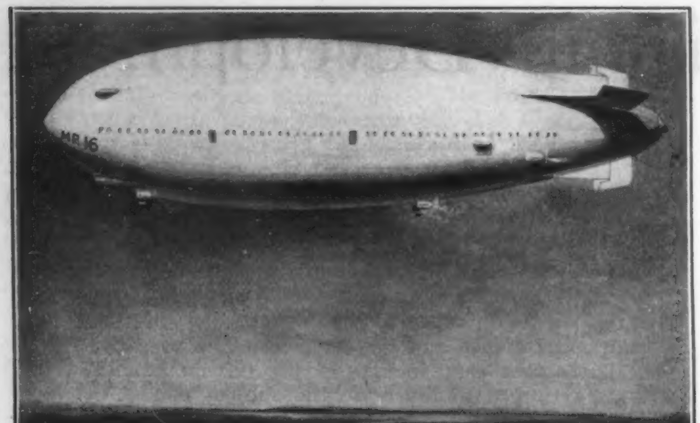


Fig. 2—Preliminary Design of Metalclad Airship
This Ship Which Was Designed To Carry Express and Mail Had a Volume of 1,600,000 Cu. Ft. The Fins Shown Are of the Old Type

To solve this problem of reducing to proper proportions the parasite difficulties of airship operation was the reason for the organization of the Aircraft Development Corporation. Our solution now appears in the Metalclad design, which, though not yet demonstrated in actual flight, has reached a point where definite predictions can be made and engineering discussion invited. Let us first consider the events leading up to the present development.

Progress of Development

The first suggestion in the line of a metal airship, of which we have any record, is due to Father Lana in 1670. He proposed a car to be supported by four hollow spheres of very thin copper, from which the air was to be exhausted, thus making them lighter than air. Propulsion was to be by a sail, which was of course a fallacy, but otherwise the scheme was scientifically sound. It was impossible of realization, not through any violation of natural laws, but because no known material of such necessarily thin gage could stand the outside pressure. With all the improvement in materials in the last three and one-half centuries we are still far from any possibility of a *vacuum* airship. By filling the hull with a light gas, however, and thus replacing the severe compressive stresses with a preponderance of tensile stresses, the *metal* airship becomes thoroughly feasible.

In 1897 an Austrian named Schwartz designed a sheet aluminum airship, the construction of which was actually finished after his death. It was inflated by fabric gascells and got into the air but it could not be operated due to serious faults in the structure, powerplant and controls.

Zeppelin's first metal-framed airship was also a failure but his genius and perseverance won out in the end, and the duralumin framed Zeppelin became the world's standard in airship construction. In a way it had too much success for the good of airship development generally for, although the Zeppelin itself was greatly improved by refinements of design and construction, it naturally discouraged further radical changes, especially during the War. Since the War however the very attractive possibilities of metal construction have proved irresistible.

Already the all-metal airplane is a practical reality, being made from the same duralumin that had previously been developed for the *framing* of airships. The success of the all-metal airplane is now in turn a great stimulus toward the elimination of dry goods as a covering for airships. The solution of this problem has involved a combination of:

(1) Inquiry into the general feasibility of the project
(2) Search of materials and methods already available
(3) Invention and development of means to fill the new requirements
(4) Detailed calculation and experiment to establish a sound design
(5) Similar research as to means of practical production

Five years, representing about 30 man-years has been spent on this program which is now practically finished. The general feasibility of the Metalclad airship has been mathematically and experimentally proved. Sheet duralumin in quality now available proves immensely superior to fabric in almost every respect. Means have been devised for utilizing to full advantage the fundamentally superior qualities of the material. The stresses and aerodynamic characteristics have been most carefully studied for a great variety of operating conditions, showing a strength, stability, and general efficiency greater than any previous airship. Production methods and equipment in themselves have involved considerable new development to suit the requirements of the design. Successful research in this direction indicates that Metalclad airships, with all their other advantages, can ultimately be built more cheaply than the fabric covered type.

The first design to be laid out with any attempt at completeness was for a ship of 1,600,000 cu. ft. which is shown in Fig. 2. When this size was chosen it was with the idea that it was about the smallest Metalclad unit which could be made a practical success, the original thought being that some sacrifice in lift would have to be made to gain the practical advantages of metal construction. The first big surprise came with the weight statement of this ship which showed an actual reduction in the total weight compared to fabric construction, with a strength and over-all efficiency substantially better than the somewhat larger Shenandoah.

The assumed duralumin plating weighed approximately four times more per square foot than the fabric cover

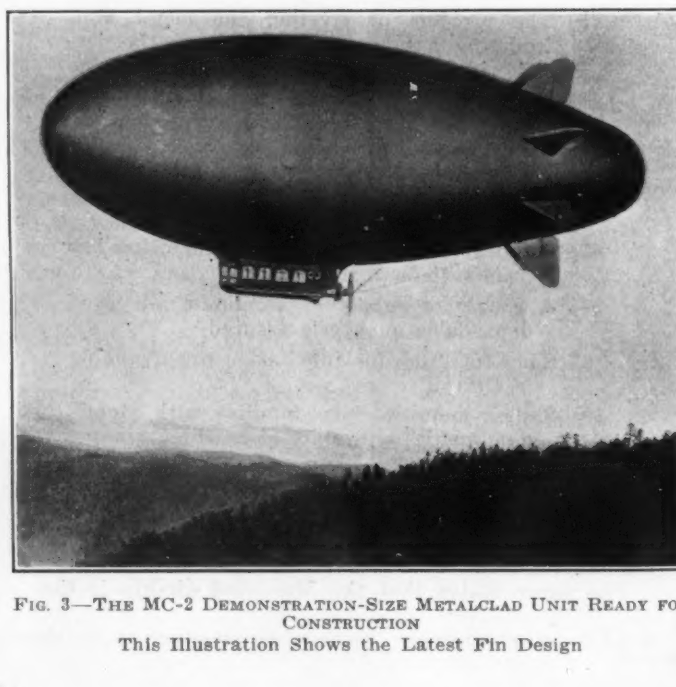


Fig. 3—The MC-2 Demonstration-Size Metalclad Unit Ready for Construction
This Illustration Shows the Latest Fin Design

of the Shenandoah. Yet the total weight was less! The result was due largely to the manner in which the single metal surface was made to serve a number of different purposes, made possible by the homogeneous character of the structure.

Considered as a cover, the metal serves the same purposes as the fabric outer cover but does it more efficiently by eliminating the flapping and moisture absorption so common to fabric. That is, however, only the beginning. In the Metalclad ship the surface plating also holds the gas and, in combination with the frame members, carries most of the stresses. The general principle of construction is similar to that of a steamship, in which the frame and plating are neither of them structurally self-sufficient, but each supports and reinforces the other. Thus the present design is far more than and essentially different from a mere metal-*covered* airship.

This saving in weight made possible by the unit structure and by refinements in design, in turn brought up the question as to whether we could not produce a still smaller size ship for demonstration purposes. Study in this direction has finally crystallized into a size of only 200,000 cu. ft. volume, about one-tenth that of the Shenandoah, and smaller than has been attempted before for any rigid airship. This demonstration unit, which is illustrated in Fig. 3 and is designated the MC-2, will have a better performance in most respects than that of a nonrigid airship or "blimp" of similar size. Thus although too small for economic commercial service, this ship will have characteristics of great value for scouting, training and other special purposes. Tentative designs and performance calculations have also been made for ships of 80,000, 500,000, 1,200,000, and 5,000,000 cu. ft. respectively. But reports recently appearing in the press of the alleged *completion* of plans for the last-named size are, to say the least, greatly exaggerated. The 200,000-cu. ft. size is the only one ready for immediate construction. In many respects this small size will present more conclusive demonstration of the Metalclad principle than could a larger unit in which the weight consideration would not be so serious. The results depend upon certain basic principles that will now be described.

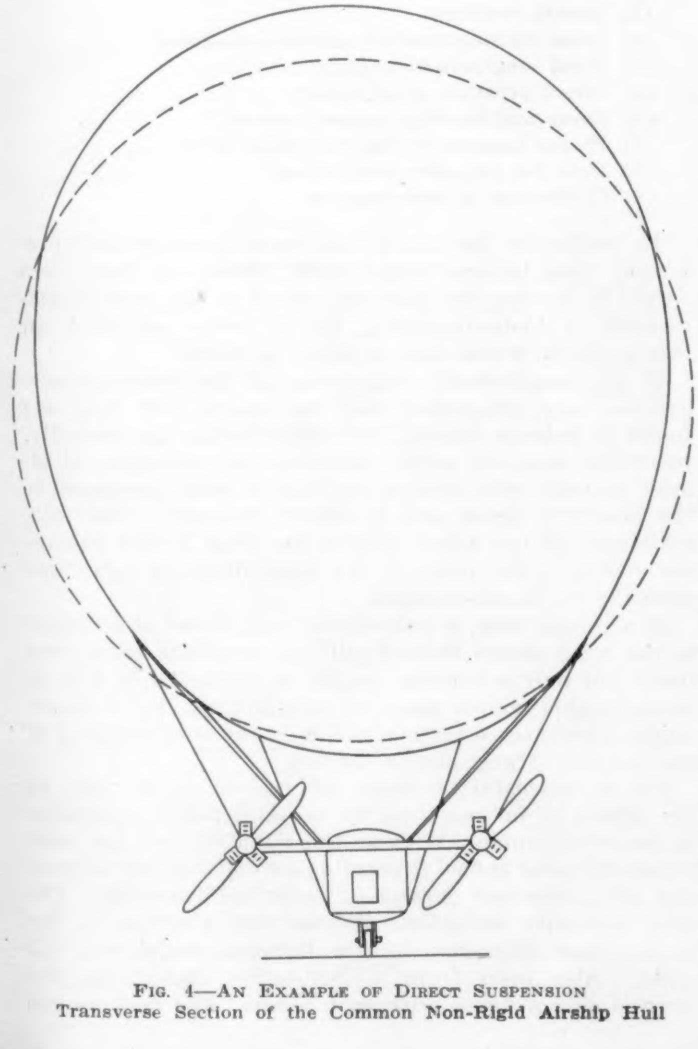


FIG. 4—AN EXAMPLE OF DIRECT SUSPENSION
Transverse Section of the Common Non-Rigid Airship Hull

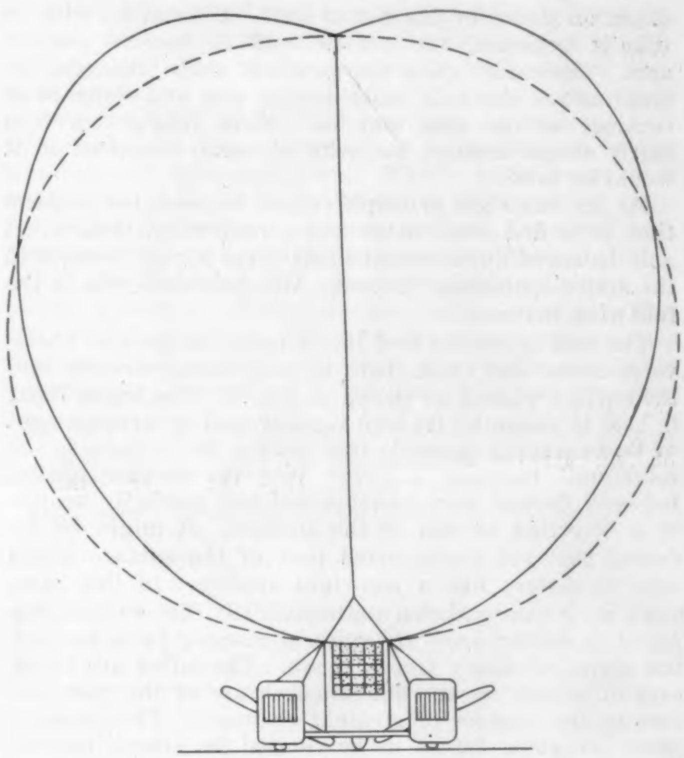


FIG. 5—ANOTHER EXAMPLE OF DIRECT SUSPENSION
Transverse Section of a Non-Rigid or Semi-Rigid Airship with the Internal Suspension-Members Longitudinally Distributed

THEORY OF THE STRUCTURE

The most fundamental and obvious requirement for any metal structure is that it shall not be repeatedly strained beyond the elastic-limit of the material. In effect this necessitates a thoroughly rigid non-deformable structure. If this rigidity were to be maintained throughout the entire hull by structural stiffening alone, the weight would be almost prohibitive. Much therefore depends on building the hull originally of such form and arrangement that the tendency toward distortion is reduced to the minimum. A non-rigid airship is a familiar example of how a natural balance of forces produces a certain rigidity in an otherwise flexible envelope. Let us consider for the moment whether the same principle could be used in a metal airship.

Fig. 4 shows a typical non-rigid shape in which the load is supported by a component of direct tension in the fabric. This produces a variant of the so-called "elastic curve" or lythenary whose radius of curvature varies inversely with the height above a certain datum line. Another variation, where part of the load is distributed along the top, is shown in Fig. 5. If the pressure is raised in either of these cases the shape changes in the

direction shown by the dotted lines. Ultimately, with an infinite pressure, the curves tend to become circular arcs. Obviously when the sectional shape changes, the longitudinal elements must change also and elongate or contract as the case may be. With fabric this is a fairly simple matter, but with all-metal construction it would be fatal.

As the non-rigid principle cannot be used, the problem then is to find some shape and arrangement that is not only balanced but constant in its form for all changes in the major controlling factors. This has been done in the following manner:

The load is carried first into a perfectly circular transverse frame and from there by pure shear stresses into the surface plating as shown in Fig. 6. The frame itself is held to shape by its own rigidity and an arrangement of load-carrying elements that reduce the stresses to the minimum. Suppose, however, that the surface plating between frames were unsupported and perfectly flexible in a direction normal to the surface. It might be inferred that the unsupported part of the surface would tend to distort like a non-rigid airship. In this case, however, it can be shown mathematically that *no tendency for it to distort from its original circular form* for any but mere secondary forces exists. The latter are taken care of largely by the double curvature of the hull surface or the absence of straight elements. This permits small irregular forces to be carried by simple tension in the surface without distortion from its original shape and constitutes another important feature of the design. The net result is that the weight of local stiffening members is reduced to a fraction of what would otherwise be necessary.

Another basic principle is the manner in which the internal pressure is controlled. This is different from the system of either the non-rigid or conventional Zeppelin-type rigid airship. In the former the pressure is a somewhat arbitrary one obtained by a blower or propeller scoop. In a conventional rigid airship internal air-pressure is determined by a series of distributed holes in the hull which insure a pressure at the bottom of the hull of about zero at all times. This is necessary because of the inability of the fabric-covered hull to stand a pressure of much more or less than zero. In the Metalclad ship these ventilator holes are segregated in just the right position to produce automatically a certain positive pressure as a function of speed and in proportion to the aerodynamic forces. In this way, a proper balance of internal stresses is maintained at all speeds from zero to the maximum, and the surface is held firm against aerodynamic vibrations.

A similar method of taking air has been used before, notably in the Italian semi-rigid airships but utilized to hold the desired form and rigidity of the hull in similar manner to a non-rigid airship. On the other hand the pressure in the Metalclad has nothing to do with maintaining the *form* of the hull. The Metalclad hull retains its form regardless of pressure, the latter having to do only with the stresses and local vibrations.

Although normally not requiring any attention to pressure whatever, the design has the great advantage of *permitting* a relatively high pressure. This provides a safe margin for the operation of valves and also is a means for arbitrarily strengthening the ship to meet special conditions such as ground handling in a side wind.

Having thus attained a hull of unvarying form, homogeneous material and coordinated parts, the detailed stresses can be calculated to a degree of accuracy hitherto unknown in airships or in any structure of corresponding size. This fact alone makes possible a great increase in general efficiency providing the various outside forces acting on the ship can be determined with a similar degree of accuracy.

Aerodynamic Analysis

When a streamline body like an airship model is immersed in a stream of air in a wind tunnel, pressure is distributed over its outside surface as indicated by the dashed lines in Fig. 7, which shows the results on two typical shapes. The pressure is the maximum at the bow, becomes negative through a certain portion or portions amidships, and on a "fair" shape reaches a positive value again at the stern.

If the air is assumed a perfect frictionless and incompressible fluid the outside pressure-distribution can be calculated mathematically by the principles of hydrodynamics. For a relatively short hull this lies very close to the experimental curve near the stern. It is particularly close in the region of maximum pressure at the bow which is most important from a structural standpoint. Furthermore the effect of air friction is known to become much less for very great increases in dimensions. Thus it appears that the mathematically calculated pressures for the full-size ship may well be more exact than anything that can be derived from wind-tunnel tests.

The same analysis can be applied to almost any set of conditions, including turning and various angles of pitch and yaw, for determining the following characteristics:

(1) Inertia reactions
(2) Gross turning-moment and total fin-force
(3) Total longitudinal-stress
(4) Direct pressure at any point
(5) Shear and bending-moment curves
(6) Proper location of fins and other parts
(7) Data for propeller calculations
(8) Calibration of speedometers

In analyzing the short hull many assumptions previously used become inapplicable. Hence we have been forced to develop new methods, based on the same fundamentals of hydrodynamics; but to cover our work on this properly would take a paper by itself.

If the longitudinal components of the hydrodynamic pressure are integrated over the entire hull they are found to balance exactly. In other words, theoretically, resistance does not exist. Actually the resistance is almost entirely skin friction and this is small compared to the balanced forces due to direct pressure. The *total* resistance of our latest hull is less than 1/50th the resistance of a flat plate of the same diameter presented normally to the air-streams.

In a similar way, a well-shaped hull placed at an angle to the wind shows theoretically no resultant transverse force, but only a turning couple, as is shown in Fig. 8. Actually this couple must be counteracted by a superimposed transverse force which is in the neighborhood of the fins and largely due to the fins.

For a quantitative study of resistance as well as the details of fin reactions we are still partly dependent on the wind tunnel. With all the attention that has been put on the wind tunnel it remains a comparatively inexact and unsatisfactory means of technical research. The chief difficulty attending its use for airships is due to the vast difference in size between model and full scale. Also even from a qualitative standpoint, the tunnels do not agree with each other. The best we can

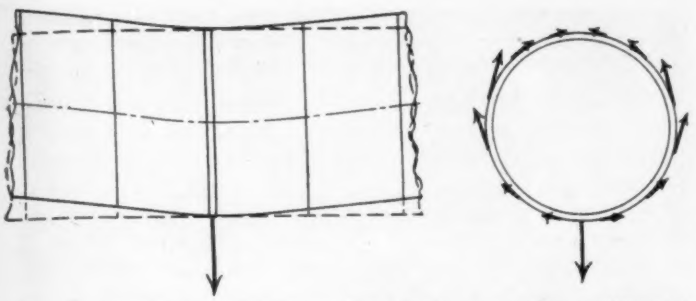


FIG. 6—AIRSHIP HULL CARRYING ITS LOAD BY THE SHEAR METHOD
The View at the Left is a Side Elevation Showing Exaggerated Shear-Strain and That at the Right Is a Transverse Section Showing Shear Forces

do for resistance measurement is to put greatest faith in those tunnels that in practical experience have shown most consistent agreement with full-scale results. Tests for stability and fin efficiency seem to be dependable as far as they go, but no satisfactory method has yet been devised of reproducing or allowing for the dynamics of curved flight in the wind tunnel.

IMPROVED HULL AND FINS

Formerly it was thought that an airship had to be long and slim to go through the air easily and have proper stability. Directly or indirectly, this false assumption has been the guiding hand of airship construction for a quarter century. Count Zeppelin based his design on it. The semi-rigid airship was created for it. The non-rigid airship was greatly complicated by it. Throughout all these years the airship has struggled with this veritable Old Man of the Sea on its back. Even now, most engineers are only beginning to see that what success the airship has had has been *in spite of* this false god, who has claimed such heavy tribute in the wreckage of ships and lives. Wholly aside from their application to Metalclad construction, the improved aerodynamic and structural characteristics of the short hull, here described, are of fundamental importance.

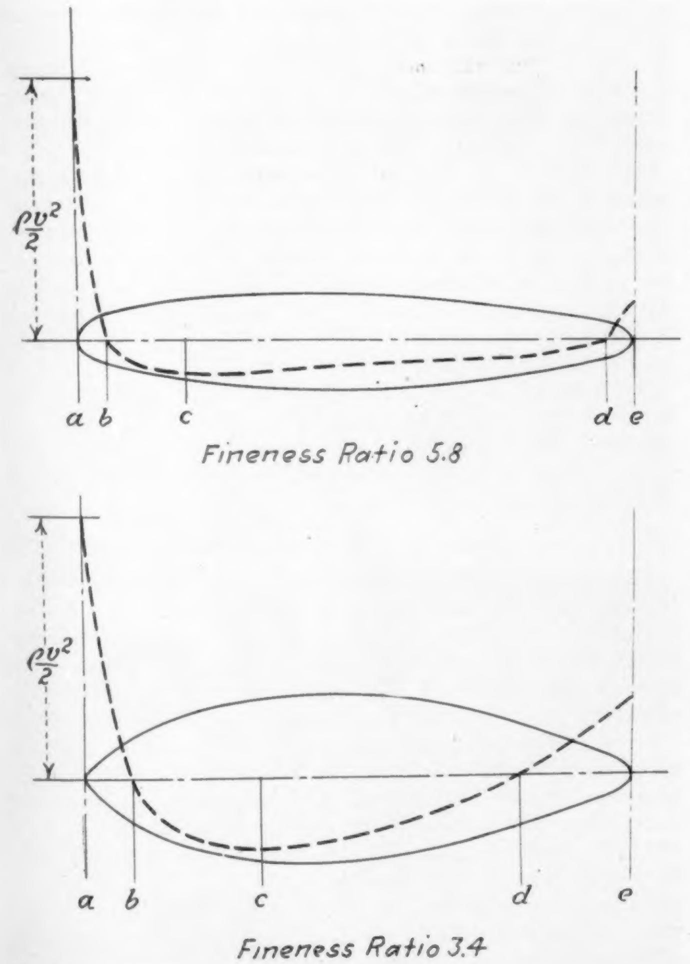


FIG. 7—DISTRIBUTION OF SURFACE AIR-PRESSURE OVER AIRSHIP HULLS IN MOTION
Note How the Shape of the Curve Varies with Different Fineness-Ratios

For the Metalclad ship, good structural efficiency requires a fairly short and compact hull. We approached the problem confident that with the proper curves such a shape could be made efficient. The results are rather surprising. According to the best evidence available,

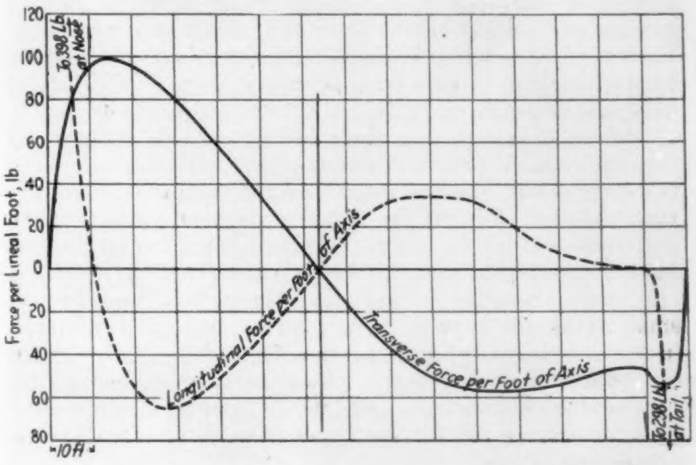


FIG. 8—HYDRODYNAMIC REACTIONS ON THE MC-2 HULL
These Are for an Angle of 10 Deg. and a Velocity of 50 M.P.H. without Fins, Using the *E-H* Hull Curve

the Navy wind tunnel, our new hull form has a lower resistance for equal volume than any shape hitherto produced. This is for a length-diameter or fineness ratio of only 2.8 to 1.0 compared with 7.2 to 1.0 for the most recent Los Angeles and 8.6 to 1.0 for the Shenandoah.

The improvement in aerodynamic stability is even more striking. With our new fin arrangement totalling 17 per cent *less area* than the Shenandoah surfaces, for equal volumes, *the stability and control is more than twice as good*, and studies now under way give promise of still better results. This almost revolutionary improvement is largely due to the detail of the fin arrangement in which a greater number of small units, in this case eight, is used, instead of the four that became conventional about 10 years ago. The static stability of the MC-2 is somewhat excessive, but the larger Metalclad units with distributed loads and our internal corridors can be made about right. The aerodynamic lift is almost double that of the Shenandoah for equal volumes. Various outside forces having been established, the next step was to determine the effect on the full-size structure. This was done on the fins by sand loading to destruction as shown in Fig. 9, in similar manner to the testing of airplane surfaces. The full-size metal fins broken in this way showed a load factor of 5, with a total weight considerably less than the old wood and fabric surfaces. Other parts of the ship were tested in a similar way, a section of a transverse girder undergoing a test being shown in Fig. 10.

The next problem was to find some way of running an overload test on the hull itself. Even if desired, this could not be done on the full-size ship because its lift is strictly limited by its gas content and aerodynamic

properties. Many tests had, of course, been made on individual girders, plating and fittings, but a practical demonstration was also wanted of the structure as a whole. This was done by a hydrostatic or "water model."

To go into the general theory of an airship water-model is not necessary. The reduced-scale model is simply hung upside down as shown in Fig. 11, and filled with water whose weight acts in reverse proportion to the gas lift in the full-size ship, other forces being also applied in proper proportion. The usual scale of a water model is the "natural" one of 1/30 the linear dimensions. This produces surface stresses just equal to those in the full-size ship. If the model is built to a larger scale than 1/30, using the same surface materials, it corresponds to overloading it, as if it were filled with a heavier fluid. For the metal water-model a size of 1/14 was chosen, which when inflated to a corresponding pressure-head is equivalent to overloading the full-size ship about 5 times and subjecting it to a pressure 65 times as great.

This is so severe that the effect of surface stiffness of the material is practically eliminated. In addition, the framing was reduced to the minimum and made relatively more flexible than in the full-size ship. In figures, the water-model hull, including its internal structure, weighs 51 lb. and holds over 2½ tons of water. It has not only the strength to carry this large overload but is rigid under all conditions, including arbitrarily applied bending-moments that are far greater than any which could be expected in flight. In general the water-model results checked so closely with the calculated stress values that for future units it will probably be unnecessary to make water-model tests.

Reserve Strength

Referring back to the full-size ship, we must now consider the numerical value of the safety factor. This means little in an airship however without a full knowledge of the conditions imposed and a means of comparison with other ships. For the MC-2 we have analyzed the following limiting conditions:

(1) Full speed 70 m.p.h.; zero yaw and pitch; maximum internal or blow-off pressure at the valve 100 mm. (3.937 in.) above the outside air pressure

(2) Minimum pressure, for full speed, above atmosphere assumed one-half the maximum hydrodynamic-pressure. Other conditions same as (1). Analyzed for nose stiffness only

(3) Speed 50 m.p.h.; pitched downward 10 deg. relative to air, but horizontal relative to ground; minimum pressure above atmosphere one-half the maximum hydrodynamic-pressure

(4) No power; zero angle; internal pressure at bottom 0 mm.

(5) Speed 45 m.p.h.; pitched upward 10 deg. relative to air, but horizontal relative to ground

(6) Speed 45 m.p.h.; pitched 25 deg. downward relative to ground and 4 deg. downward relative to air; minimum pressure one-half the maximum hydrodynamic-pressure. This case analyzed for nose stiffness and scoop capacity only

(7) Same as (3) except ship momentarily pitched down in nose 10 deg. relative to air and 30 deg. relative to horizontal

(8) Same as (4) except with surplus load causing descent of 500 ft. per min.

(9) Moored as kite balloon; pitched 5 deg. up at nose; elevators 8 deg. up; wind 70 m.p.h.; stern tank full and enough load taken from car to make ship 1000 lb. light.

(10) Moored at the ground 4 ft. from the bow of car; no fuel in stern tank and enough more load taken from car to make ship 1000 lb. light

No part of the ship, for any of the above conditions, shows a safety factor less than 3. All essential or critical parts are still stronger, as shown by some 600 detail stresses.

With the Shenandoah disaster still fresh in mind, to compare the longitudinal strengths of the two ships is of particular interest. The worst bending-moment, for ordinary operation, considered in the design data of the Shenandoah was reached at an angle of pitch of 6 deg. relative to the air, and at a speed of 46 m.p.h. Assuming hydrogen inflation at the blow-off pressure of 10 mm., a safety factor of 1.68 is indicated in the top longitudinals. The MC-2 under the same conditions, except with blow-off pressure of 100 mm., shows a minimum longitudinal factor of safety of 9.61. But that is not all. Applying the effect of a vertical gust, by using the typical case given in National Advisory Committee for Aeronautics Report No. 204, the effective angle of pitch of the MC-2 imposed by such a gust is only 3.1 deg. as compared with 4.8 deg. for the Shenandoah.

But the above figures assume a uniformly distributed gust, one that is equal along the whole length of the ship, and a control 100 per cent effective in preventing any actual tilting from a horizontal position. The latter assumption is particularly unjustifiable for the extremely slender and unstable Shenandoah. The required angular movement of the control surfaces to resist the same gust would be more than four times greater for the Shenandoah than for the MC-2. The further net advantage is not exactly in this ratio, but a conservative estimate places the total longitudinal safety factor of the MC-2, under these conditions, at fully eight times that of the Shenandoah. The torsional strength is still greater.

In addition we have the advantage that even an actual break is not as serious as with a fabric covered frame. This has been amply proved by experience with the water-model, a full-size section and the fins. This last is brought out in Fig. 9, which shows one of the fins after buckling with a five-times overload. Even in the broken condition it still hangs together and will carry not only the normal load but the full overload.

Thus no concern need be felt as to the Metalclad breaking in two as the Shenandoah did. This type of failure simply is not a factor, as actually in this case the transverse stress due to the direct pressure is in excess of the longitudinal stress.

Internal Pressure Control

Factors of safety, no matter how large, are of no avail if they do not take care of all the stress-producing variables. Of these, pressure is obviously one of the most important. The effect of maximum pressure has already been discussed. At minimum pressure the factor of safety is, in general, even greater. But a small *variation* in pressure at the lower end of the scale produces much more serious results. For example, if all air-intake openings in the Shenandoah were sealed the ship would be structurally collapsed by a descent of approximately 100 ft. Any airship of any type absolutely depends on having adequate airflow into the hull.

As mentioned before, the Shenandoah and similar ships were necessarily designed for an operating air-pressure of about zero, the object being to keep the pressure difference at all points as little as possible between outside and inside. This condition can be satisfied with a shape like that of the Shenandoah, because its outside

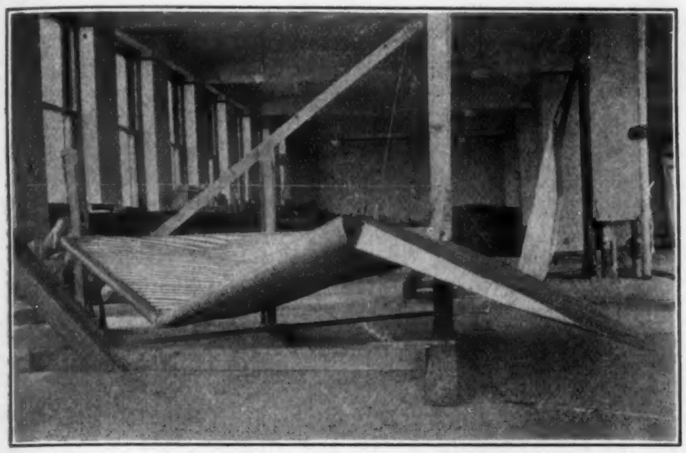


FIG. 9—FULL-SIZE FIN AFTER SAND LOADING
In this Test before Failure Occured the Fin Sustained a Load That was 5 Times as Great as That to Which It Would Normally be Subjected

pressure curve lies very close to zero throughout most of its length, the bow being an exception that is taken care of by a special concentration of girders. The MC-2, on the other hand, is designed for normal operation at a pressure equivalent to the maximum velocity-head of air on the outside, about 60 mm. for full speed (See Fig. 7, point *a*).

The question might be asked offhand whether any ship that depends on pressure for its operation would be as safe as one that does not. But further analysis shows the question to be almost entirely one of definition, except with reference to other features of the design. *Zero* pressure is only a special case of *any* pressure. In either case it must be under very definite control. Referring again to Fig. 7, the most direct method of obtaining zero internal air-pressure is by ducts communicating with the outside at points *b* and *d*. But any other pressure within the limits of the curve can be utilized in the same way and with equal assurance. In the Metalclad ship the surface plating is obviously better suited to carry tension than compression. Therefore the inside pressure is chosen to balance the *higher* of the outside pressures which is only another illustration of the words of Count Zeppelin, "The forces of nature cannot be eliminated but they can be balanced one against another."

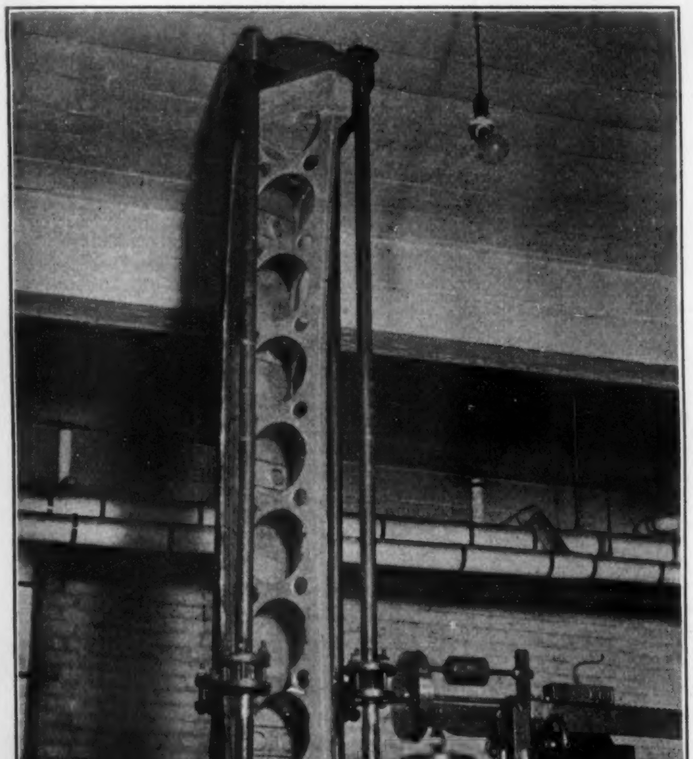


FIG. 10—SECTION OF A TRANSVERSE GIRDER UNDER TEST
This Test Is Typical of Those to Which the Parts of the Metalclad Airship Were Subjected

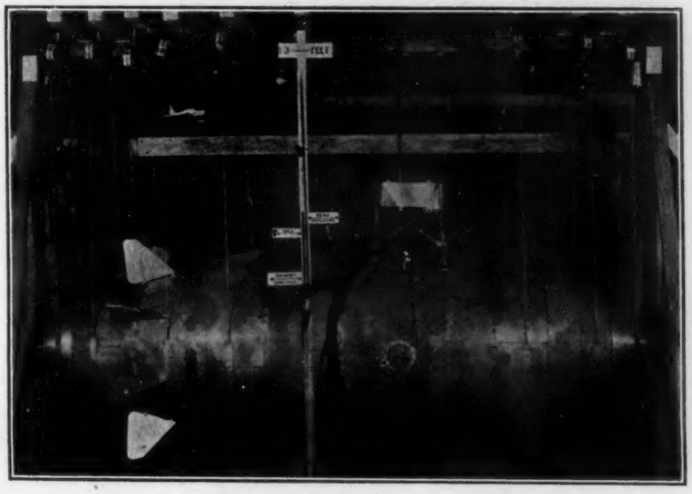


FIG. 11—WATER MODEL OF THE METALCLAD AIRSHIP
This Is Probably the Largest Water Model of an Airship Ever Built, Supporting 5125 Lb. of Water. When Hung Upside Down as Shown and Filled with Water, the Equivalent of an Overload of 400 Per Cent on the Full-Size Airship Was Obtained

Calculation of the necessary size of openings for any speed of descent presents no serious difficulty providing a definite pressure-drop or working-head can be assigned to the inflowing air. In the Shenandoah this was an extremely small and uncertain quantity at all speeds. In the MC-2, it is definitely fixed at 30 mm. for full speed. With lower speeds the figure is necessarily reduced in approximate proportion to the square of the speed, being always at least half of the maximum dynamic wind-pressure. In other words half of the theoretical pressure can be applied as head to produce the inward airflow.

With the power off and no speed of advance, no internal pressure is necessary. Even in this case however the gas is subject to contraction if the ship is dropping to lesser altitudes, and a corresponding air supply or ventilation must be allowed for. The working head for the inward air-flow in this case is taken as equal to the weight per square foot of the surface plating. In this way, openings are provided for the required air delivery, of such a size as not to allow any actual sucking in of the plating, although indications are that the hull has considerable strength in this direction.

HULL CONSTRUCTION

The hull is entirely of metal except for an internal fabric diaphragm separating the ballonet or air-compartment from the gas above. This diaphragm yields

with varying proportions of gas and air in the same way as the bottom portion of the gas cells in a conventional rigid airship. In the MC-2 however the balloonet diaphragm will normally be kept flat down against the bottom of the hull, in effect making a metal container of the entire hull throughout the greater part of which the gas is in direct contact with the metal. This highly desirable arrangement naturally depends upon having a reasonably gas-tight surface.

Early encouragement of the possibility of gas-tight seams in duralumin sheet was had by analogy with steel gasometers that are much tighter and more satisfactory than any made of fabric. Many different types of seam were tried without success. However it was apparent that if the same rivet spacing and other dimensions as used in gasometer practice could be reduced in proportion to the thickness of sheet, the *results* should be comparable. The big trouble was the enormous number of tiny rivets, which is about 3,000,000 in the small MC-2, that would be required. This problem has been solved by our successful development of a special riveting machine illustrated in Fig. 12, that automatically puts in more than 5000 rivets per hr. and does it much better than would be possible by hand.

The only thing that we did not have in the duralumin seam was the rust that works into the seams of a steel gasometer and plays an important part in making it tight. This is supplied to our seams independently by a specially prepared seam dope. Again we attain rather surprising results. Tests have averaged less than one-tenth the leakage usually specified for goldbeater-skin fabric. This includes results throughout an extreme range of temperature and after very pronounced vibration, although experiments at the Bureau of Standards indicate practically no vibration from aerodynamic causes. The strength of our standard seam is greater than the yield-point of the material.

The material itself is a development of the duralumin manufacturers who have cooperated in a very fine way to render their product available in the form needed.

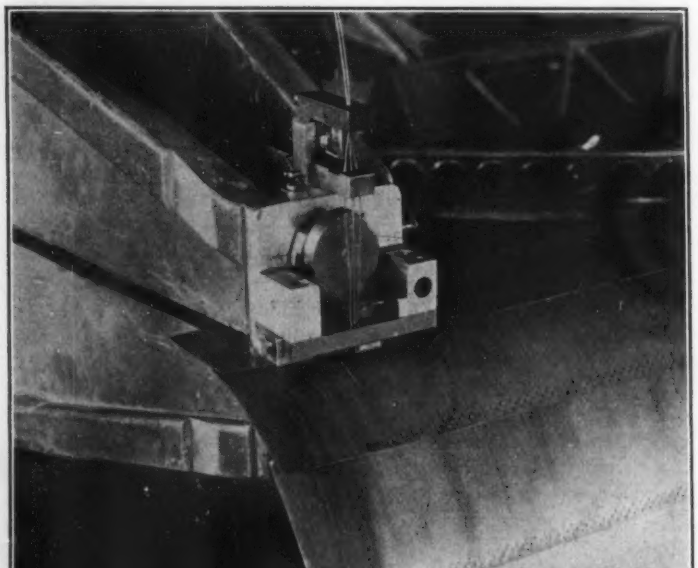


FIG. 12—AUTOMATIC RIVETING MACHINE IN OPERATION
This Machine Will Drive over 5000 Rivets per Hr. and Do the Work Better than It Can Be Done by Hand

The art of rolling a very long and wide fine-gage duralumin sheet that is unusually flat for the tempered condition and with the gage closely controlled is a peculiarly American work of the last 3 years and beyond anything that has been done in Germany, England or France. Duralumin, although much less corrosive than steel, still needs a protective coating for the best results; and we have found an extremely light and efficient preparation for the purpose.

The patterning of the surface follows the same general principles as with fabric, but special equipment had to be devised to take care of the greater accuracy required. The internal frame-members are simple in form but have involved practical difficulties of shaping to the exact curve and angle.

On account of its small volume which is about equal to *one* of the gas cells in the Los Angeles, the MC-2 will have only a single gas compartment, and a single outside-hung car as shown in Fig. 13. Larger Metalclad units will have compartments divided by partitions that will bulge in the direction of the pressure difference. They will also have most of the useful load carried in either internal or external corridors that are located preferably one on each side. The construction also lends itself admirably to the use of engines housed within the hull. It is expected to erect the hull in a vertical position, the small ones as a whole, the larger ones in two or more sections corresponding to the compartments in the completed ship. This permits doing most of the work by production methods on or near the floor.

With the MC-2 the gas, either hydrogen or helium, will be put in under a slight pressure while the hull is still in a vertical position. This is done by direct displacement of the air that is removed at the lower or stern end including the impure mixture at the surface of separation. Careful analysis shows that the latter, under proper conditions need not exceed 10 per cent. After inflation to a pressure insuring extra strength, the hull is hauled down to its designed position and the car bolted in place. Ordinary replenishment of buoyant gas will be by a service connection with the hull in normal position.

OPERATION

To have a ship such as the MC-2 as simple as possible to handle, not only in the air but also on the ground, is considered desirable. In both cases this is primarily a matter of aerodynamic stability as before mentioned. These improvements applied to the MC-2 mean that it can be handled in the air by half the usual crew for a ship of its size, at the same time under much better control. It will also be possible to use very simple methods of mooring and ground handling. The principle of bow mooring is bound to be widely used and it should be particularly appropriate to ships with improved stability, extra strength and resistance to exposure. Our recent developments in mooring-tower construction are outside the scope of the present paper.

Due to its combination of perfect rigidity and its ability at the same time to carry considerable internal pressure, the Metalclad can be operated in flight either like a conventional rigid airship without reference to pressure, or like a non-rigid airship by watching the pressure manometer, and regulating the altitude accordingly. The latter method will be usually preferable because in that way the hull can be kept full of gas and the maximum advantage taken of its extremely good gas-holding properties.

We are recommending that hydrogen gas be used for

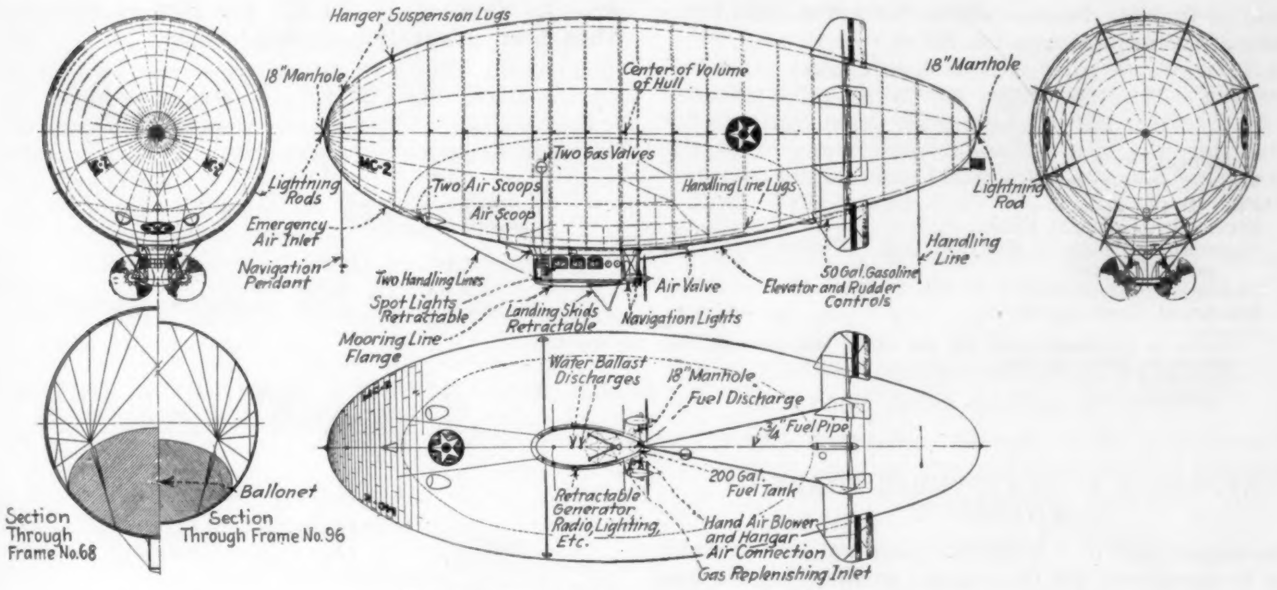


FIG. 13—GENERAL ARRANGEMENT OF THE MC-2
This Metalclad Airship Has a Gas Capacity of 200,000 Cu. Ft. Its General Characteristics Are Presented in Appendix 8

inflation on account of its availability, cheapness, lifting qualities, and the fact that it can be used for reserve fuel, which will reduce the weight of water ballast recovery apparatus. That hydrogen in a metal hull is at least as safe as gasoline in a metal tank should be fairly obvious. If helium is desired, however, it can be used to better advantage than in a fabric airship because of the almost negligible leakage through the metal hull, and the higher gas purity that can be maintained. Even with helium, it is a great asset that the surface of the ship itself is fireproof.

Several questions have been raised as to the effect of the high thermal and electrical conductivities of the hull, the common idea being apparently that these would be unfavorable operating-factors. Actually they are just the reverse.

The metal surface heats-up considerably in the sun, when not in motion, but this is usually an advantage at the start. In operation, thermal disturbances in the lift are eliminated by keeping the gas at the same temperature as the outside air. Indications are that the highly conductant metal surface tends to approach this ideal when in rapid motion through the air, most of the radiant heat being carried off again as fast as received.

In respect to electric conductivity all authorities seem to be agreed that the new ship will be absolutely static proof and almost, if not entirely, lightning proof. The only danger conceivable from lightning is that a sudden charge might cause a momentary current so severe as to produce local fusion of the material. This has been observed in the case of wires where the current is restricted to a one dimensional flow, but for a flat surface it seems at least reasonable to suppose that any charge would splash out over enough area to prevent melting through. Further evidence on this point is being sought.

Methods of inspection and repair, although entirely different from those that apply to fabric, are for the most part equally simple. It is hoped and expected that they will be called into use but seldom.

ACKNOWLEDGMENT

One of the fine experiences of this entire development enterprise has been the splendid spirit in which cooperation has been extended from every source requested Various members of the personnel of the Army, Navy and Post Office Air Services; the National Advisory Committee for Aeronautics, and the Bureau of Standards have made available a mass of technical information that has proved invaluable in aiding in the progress of the work. In carrying on the necessary experimental work especially valuable assistance has been given by the Ford Motor Co., particularly the Stout Airplane Division, and the General Motors Corporation who have extended to our engineering staff the unrestricted use of laboratories, experimental machine-shops and other facilities.

SUMMARY

In line with the universal application of metal to all types of vehicle, the Metalclad airship also must come. Its development to date gives sound promise of these results:

(1) A substantial airship hull that is
 (a) Proof against static sparks
 (b) Durable in weather
 (c) Determinate in stresses
(2) A ship of unprecedented efficiency
 (a) Structurally
 (b) Aerodynamically
 (c) Practically
(3) A fireproof structure in which hydrogen gas can be used both for buoyancy and reserve fuel as safely as gasoline or, in which helium may be used with maximum economy and effect
(4) An economical aircraft whose first cost in materials is low, as well as its cost of upkeep and renewals
(5) A long-range vehicle that besides needing no right of way is independent of hangars, except for "dry-dock" purposes
6) A commercial carrier destined some day to carry substantially all first-class passengers, all mail and all express on the longer routes over land and sea

APPENDIX 1—COMPARISON OF METAL AND FABRIC

The following is a comparison of machine riveted duralumin sheets as used for the hull of the MC-2, with

a sheet of four-ply fabric suitable for a non-rigid fabric airship of the same size as the MC-2.

	Metal	Fabric
Thickness, in.	0.008	0.021
Weight, lb. per sq. ft.	0.14[a]	0.11
Pull, lb. per ft.[2]	3,200	600
Strength to Weight Ratio	23,000	5,500
Approximate Rate of Buoyant Gas Diffusion per 24 Hr., liters per sq. meter	0.1[a]	10.0
Thermal Conductivity[3]	31	0.004
Electrical Conductivity[3]	25	0.000,000,000,000,000,000,000,2[b]

[2] Value is at elastic-limit for the metal and on time test for the fabric.
[3] Based on silver as 100.
[a] Including seams.
[b] Approximately.

APPENDIX 2—TRANSVERSE SHAPE OF ENVELOPE

The shape taken by a uniform cylindrical section under shear is considered for two cases. In the first, the load is concentrated on the transverse frame, the weight of the envelope is neglected and only static forces are considered; in the second the effect of a skin weight of W lb. per sq. ft. on a cylindrical section is considered. The diagrams used in connection with these two cases are shown in the left and right portions of Fig. 14.

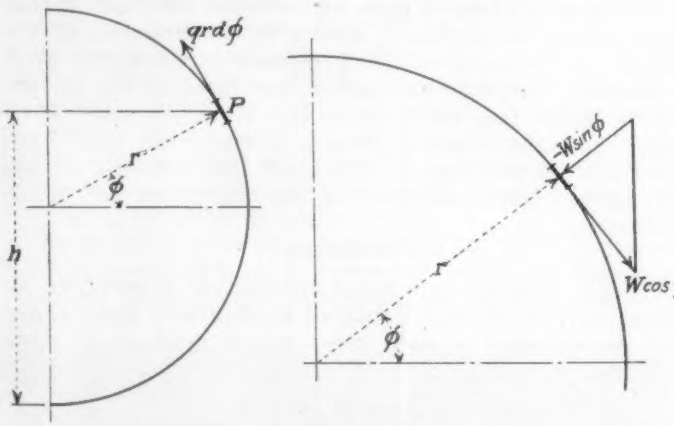


FIG. 14—DIAGRAMS ILLUSTRATING THE SHAPE TAKEN BY A UNIFORM CYLINDRICAL SECTION UNDER SHEAR

In the Drawing at the Left, the Weight of the Encelope Is Neglected and Only Static Forces Are Considered. In the Drawing at the Right the Effect of a Skin Weight of W Lb. per Sq. Ft. on a Cylindrical Section Is Considered

CASE I

Let

k = unit lift of gas

p = pressure at bottom = 0

Q = total shear on section

q = unit shear at point P

The differential shear force acting on any very small arc is

$$qr\,d\phi = (Q/\pi)\ (\cos\phi\, d\phi) \qquad (1)$$

by integration of longitudinal stress (See Appendix 3 for formula for q). The portion of Q in equation (1) that is unloaded onto any very narrow circumferential strip is $(dQ/dx)dx$.

Let t = the circumferential tension per foot on the same extremely narrow cylindrical strip acted on by $dQ/dx = L$, where L is the lift per foot of axial length. Then from integration of shear forces

$$\begin{aligned} t &= (L/\pi) \int \cos\phi\, d\phi \\ &= (L/\pi)\ \sin\phi + C \\ &= (L/\pi)\ \ (1 + \sin\phi) \\ &= Kr^2(1 + \sin\phi) \end{aligned}$$

But from gas head

$$\begin{aligned} t &= Krh \\ &= Kr^2(1 + \sin\phi) \end{aligned}$$

Therefore section remains circular as tension from gas head at every point balances that due to integration of shear forces. Any *increase* of pressure, at the bottom, above the zero value here assumed can be taken as applied uniformly throughout the hull, thus still maintaining the circular shape.

CASE II

Circumferential tension at bottom due to skin weight

$$t_w = Wr$$

At any other point

$$\begin{aligned} t_w &= Wr + \int Wr \cos\phi\, d\phi \\ &= Wr\ (2 + \sin\phi) \end{aligned}$$

Equivalent pressure due to skin weight

$$= -W \sin\phi$$

or tension due to total pressure

$$t = Kr^2\ (1 + \sin\phi) - Wr \sin\phi$$

and

$$t - Wr = r\ (Kr - W)\ \ (1 + \sin\phi)$$

But from integration of shear forces

$$t = (dQ/\pi dx)\ \ (1 + \sin\phi) + Wr\ (2 + \sin\phi)$$

in which

$$dQ/\pi dx = Kr^2 - 2\,Wr$$

or lift-load per foot and

$$t - Wr = r\ (Kr - W)\ \ (1 + \sin\phi)$$

which is identical with the previous result. Therefore the section remains circular for uniform skin weight.

GENERAL CASE

The aerodynamic pressure due to pitching or circular flight has a component perpendicular to the ship's axis which may be approximated by a straight-line function plotted on the diameter of symmetry.[4] Referring back to Case I, it may be seen by inspection that the result is independent of the numerical values of either K or p. As long as the aerodynamic pressure is a straight-line function, it may be expressed in the form $p = K_1 h_1$, where h_1 is the perpendicular distance from any point P to the line represented by $P = O$. Thus the total transverse-pressure on any one section is a volume function.

The reacting forces are either inertia, or surplus-lift or load. These, whether taken off by envelope shear,

[4] See National Advisory Committee for Aeronautics Technical Note No. 192.

uniform envelope weight, or gas weight, can all be resolved into the same straight-line function.

Therefore a transverse section of a fully inflated cylindrical envelope remains a circle for any combination of static and aerodynamic forces providing the load or inertia reaction is distributed by some combination of:

(1) Envelope shear
(2) Uniform loading over the envelope surface
(3) Uniform loading per unit of volume

The result is independent of the magnitude of bending moment or shear unless these are sufficient to cause a reduction of the effective structural-section to anything less than a full circumference.

APPENDIX 3—GENERAL FORMULAS FOR HULL STRESSES (See Fig. 15)

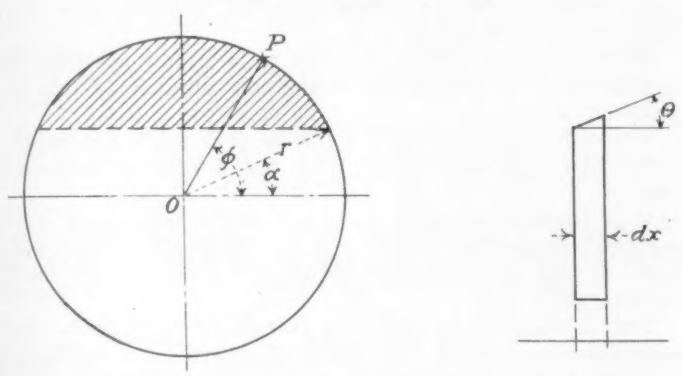


FIG. 15—DIAGRAMS SHOWING HULL STRESS
The Diagram at the Left Relates to the Discussion of General Formulas for Hull Stresses; That at the Right Illustrates the Determination of the Unit Shear in a Tapered Section

α (usually negative) = angle to bottom level of gas
F_a = longitudinal force due to aerodynamic pressure and thrust-resistance forces
F_p = longitudinal force due to gas pressure
F_x = any other longitudinal force such as a suspension component
ΣF = total longitudinal-force
ϕ = angle to any point P
K = unit lift = 0.068 lb. per cu. ft. for hydrogen
M_a = bending-moment due to aerodynamic forces and incidental differences in loads
M_p = gas-pressure moment
M_x = bending-moment due to longitudinal components of suspension, control lines and the like
M_y = transverse bending-moment due to loads and gas lift
ΣM = total bending-moment
p = pressure of gas at bottom of maximum section
p_a = outside aerodynamic-pressure at any point P
Q = total transverse-shear } counter - clockwise
q = unit shear (circumferential) } is positive
R = longitudinal radius
r = transverse radius
T = longitudinal tension
t = circumferential tension
Θ = angle between axis and a tangent to the *meridian* at P
W = unit weight of envelope per square foot
(All in foot, pound or radian units)

LONGITUDINAL AND CIRCUMFERENTIAL STRESS

Assuming a stiff circular-section of substantially uniform gage and material, the ordinary bending-moment theory gives results demonstrated to be very close to the truth. Then the axial component of the longitudinal tension, taken tangent to a meridian at any one point P is the algebraic sum of the stresses due to bending-moments and total axial-force, or simply

$$T \cos \Theta = (\Sigma M/\pi r^2) \sin \Theta + (\Sigma F/2\pi r)$$

In proportion to the longitudinal curvature at any point the longitudinal tension helps to balance the local internal-pressure to the extent of T/R. The balance of pressure must be carried by the tension t at right angles to a meridian. Then the total local *unit-pressure* referred to any small fragment of the surface area equals $(T/R) + t/r_1$ where r_1 is the radius of curvature perpendicular to the meridian.

For the character of surface here used $r_1 = r/\cos \Theta$ which is the same ratio as the curvature of an inscribed sphere tangent around the circumference of the transverse section.

$$\therefore t \cos \Theta = r \text{ (net pressure at } P - [T/R])$$

UNIT SHEAR IN TAPERED SECTION

In this discussion the unit shear is assumed to be tangent to the meridian and perpendicular thereto.

½ of the longitudinal force at x

$$= (Mr/\pi r) \int_{\phi}^{\pi/2} \sin \phi \, d\phi$$

½ of the longitudinal force at $(x + d\,x)$

$$= [(M + dM) \div \pi(r + \tan \Theta \, dx)] \int_{\phi}^{\pi/2} \sin \phi \, d\phi$$

The difference between the two forces is

$$dq = [(-M \tan \Theta dx)/\pi r^2 + (dM/\pi r)] \int_{\phi}^{\pi/2} \sin \phi \, d\phi$$

$$q = dq/dx = [(-M \tan \Theta + Qr)/\pi r^2] \int_{\phi}^{\pi/2} \sin \phi \, d\phi$$

$$= [Qr - M \tan \Theta]/\pi r^2] \cos \phi$$

M is positive when hogging
Q (vertical) is positive when counter-clockwise
Θ is positive when opening at the right

If $Q = 0$, the maximum vertical-component per foot due to M

$$= (-M \tan \Theta)/\pi r^2 \text{ (at top)}$$

Maximum q (at side) then

$$= (M \tan \phi)/\pi r^2$$

which checks with the previous result, thus putting the vertical forces in balance.

GENERAL CASE FOR FULL INFLATION WITH SHIP IN HORIZONTAL POSITION

SUMMARY OF FORMULAS

$$T \cos \Theta = (\Sigma M/\pi r^2) \sin \phi + (\Sigma F/2\pi r) \quad (2)$$

where

$$\Sigma M = M_y + M_p + M_x + M_a$$

and

M_a is obtained by hydrodynamics
M_p is obtained by integration as $= (K\pi r^4)/4$
M_x is taken from the car-suspension diagram
M_y is taken from the bending-moment diagram

$$\Sigma F = F_p + \Sigma F_x + F_a$$

where

F_a is obtained by hydrodynamics and the wind tunnel
F_p over the cross-section area $= \pi r^2 (p + K r_{max})$
ΣFx is taken from the car-suspension diagram

$$t \cos \Theta = r [p - p_a - (T/R) - W \sin \phi + K (r_{max} + r \sin \phi)] \quad (3)$$

W, being a small factor is assumed constant

$$q = [(Qr - \Sigma M \tan \Theta)/\pi r^2] \cos \phi \quad (4)$$

"PRINCIPAL" STRESSES

$$T_{1max} = \tfrac{1}{2} (t + T) + \tfrac{1}{2} \sqrt{[4q^2 + (t - T)^2} \quad (5)$$
$$T_{1min} = \tfrac{1}{2} (t + T) - \tfrac{1}{2} \sqrt{[4q^2 + (t - T)^2} \quad (5)$$

At an angle of $\frac{1}{2} \tan^{-1} [\pm 2q/(t - T)]$ relative to the meridian

$$dT_{1min}/dL = (1/r_1) (T_{1max} - T_{1min}) \quad (6)$$
$$dT_{1max}/dL = (1/r_1) (T_{1min} - T_{1max}) \quad (7)$$

where

L = length along line of action of stress

r_1 = radius of curvature of other principal stress which crosses at right angles

Equations (6) and (7) are for plotting purposes only

Partial Inflation

The same general formulas are used, substituting F_p and M_p as follows:

$$M_p = [(Kr^4)/8]\,[\pi - 2\,\alpha + (\sin 2\,\alpha\,[2 \sin^2 \alpha - 5]) \div 3] \quad (8)$$

$$F_p = \pi r^2 p + [Kr^3/2]\,[4/3 \cos^3 \alpha - (\pi - 2\,\alpha - \sin 2\,\alpha) \sin \alpha] \quad (9)$$

In the formula for t, equation (3), for all points above the upper air-level, substitute for r_{max} the distance from the upper air-level to the center of the maximum section. For all points below the upper air-level consider $K = 0$.

Ship Inclined to Horizontal

Use the same general formulas taking into account any changes in ΣM and Q. The normal lift and load curves are reduced in proportion to cos β.

Add to ΣF the quantity

$$\underset{\beta}{\Sigma F} = \Sigma W - \Sigma K \text{ vol}) \sin \beta$$

where

β = angle of inclination of axis to the horizontal

ΣK vol = similar summation of the lift back to the same section

ΣW = summation of weights back to the section under consideration

For K in any of the formulas substitute the expression K cos β.

The inclined case of equation (3) then becomes

$$t \cos \Theta = r\,[p - p_a - (T/R) - W \sin \beta \sin \phi + K \cos \beta\,(r_{max} + x \tan \beta + r \sin \phi)] \quad (10)$$

where

x = axial distance from the maximum section to the section under consideration

When partially inflated, substitute for r_{max} the same as before, the distance being measured perpendicular to the axis.

APPENDIX 4—THE E-H HULL CURVE

Preliminary Considerations

Structural efficiency makes desirable a short fineness-ratio with a regularly varying-curvature throughout the entire central-portion of the hull.

To get a long moment-arm on the fins requires a relatively long tail.

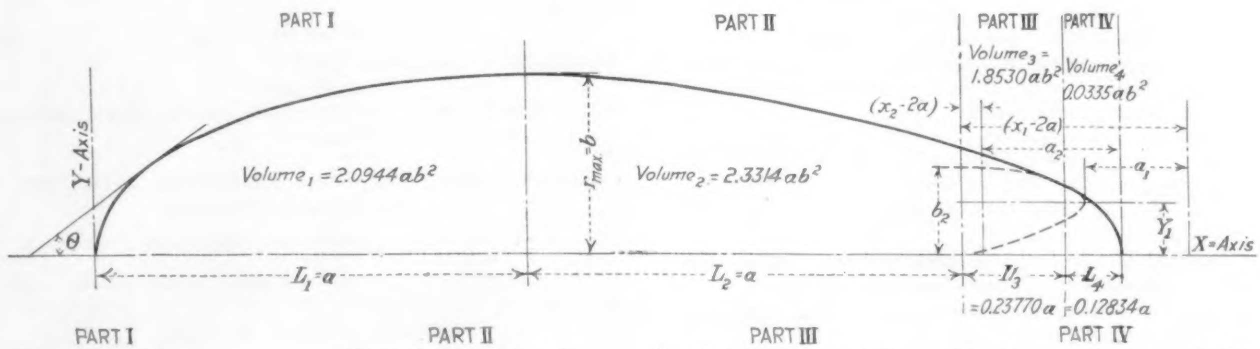
To get maximum air-reaction on them, as well as the best balance and structural support, requires the tail to be rather full at the end.

If the tail be sufficiently full it is found possible to use as many as double the customary number of fins to good advantage.

The full-scale resistance must be practically the minimum and applicable at or near the minimum fineness-ratio.

It is further desirable to have a curve with fixed geometrical properties which can be easily calculated and laid out, and which is readily adaptable to varying fineness-ratios.

The accompanying curve is calculated to provide the best combination of the above features. In working it out, reference has been made to tests on other shapes, particular attention being paid to pressure distribution. Comparison has also been made with the curves of fast swimming fish and cetaceans, data for which are on file at the Bureau of Fisheries.



PART I

Ellipse from $x=0$ to $x=a$

$$Y=\frac{b\sqrt{a^2-(x-a)^2}}{a}$$

$$\tan\theta=\frac{b(x-a)}{a\sqrt{a^2-(x-a)^2}}$$

where $a=L_1$; $b=r_{max}$

for MC-2 $\frac{a}{b}=2.4$

Center of Volume = 0.625 a from Bow

PART II

Hyperbola from $x=a$ to $x=2a$

$$Y=\frac{b\left[2a-\sqrt{a^2+(x-a)^2}\right]}{a}$$

$$\tan\theta=-\frac{b(x-a)}{a\sqrt{a^2+(x-a)^2}}$$

where $a=L_1, L_2$, $b=r_{max}$.

for MC-2 $\frac{a}{b}=2.4$

Center of Volume = 1.421 a from Bow

PART III

Hyperbola from $x=2a$ to $x=2.23770a$

$$Y=Y_1+\frac{b_1\sqrt{(x_1-x)^2-a_1^2}}{a_1}$$

$$\tan\theta=-\frac{b_1(x_1-x)}{a_1\sqrt{(x_1-x)^2-a_1^2}}$$

where $x_1=2.52232a$, $Y_1=0.29290b$, $a_1=0.23770a$, $b_1=0.14968b$

Center of Volume = 2.104a from Bow

PART IV

Ellipse from $x=2.23770a$ to $x=2.36604a$

$$Y=\frac{b_2\sqrt{a_1^2-(x-x_2)^2}}{a_2}.$$

$$\tan\theta=-\frac{b_2(x-x_2)}{a_2\sqrt{a_2^2-(x-x_2)^2}}$$

where $x_2=2.04450b$, $a_2=0.32154a$, $b_2=0.48973b$

Center of Volume = 2.282a from Bow

Total Length = 2.36604 a
Total Volume = 4.6496 ab^2
Total Surface Area = Coefficient x ab
(Approximate Coefficients Given Below)

Center of Volume = 1.095 a from Bow
Ordinate of Volume Curve $\frac{dv}{dx}=\pi Y^2$
Ordinate of Surface Curve $\frac{ds}{dx}=2\pi Y\cdot\sec\theta$

θ Is Angle the Tangent makes with Axis
x Is Measured from Bow
Y Is Measured from Ship's Axis

$\frac{a}{b}$ =	2.0	2.5	3.0	3.5	4.0	4.5	5.0	6.0	7.0
Coefficient =	11.99	11.81	11.69	11.60	11.54	11.60	11.47	11.43	11.41

Fig. 16—The *E-H* Hull Curve

This Curve Is Made up of a Series of Ellipses and Hyperbolas in Four Parts and Designed To Fit Together without Any Sudden Change in Either Angle or Curvature. The Radius of Curvature Increases Consistently, and without Any Break, from the Front of Part 1 to the Rear of Part 2. It Then Decreases, Again Reaching the Minimum at the Rear of Part 4

Equations and Geometrical Characteristics

The actual curve is made up of a series of ellipses and hyperbolas in four parts as shown in Figure 16. The curves as given are so designed as to fit together without sudden change in either angle or curvature. The radius of curvature increases consistently, and without break, from the front of Part 1 to the rear of Part 2. It then decreases, again reaching the minimum at the rear of Part 4.

APPENDIX 5—COMPARISON OF STABILITY AND CONTROL—SHENANDOAH VS. MC-2 (*E-H* CURVE)

The comparison shown in Fig. 17 is based on the assumption that the MC-2 hull, with fins but without car, is enlarged to match the Shenandoah in volume. The forces and moments are then directly comparative at the assumed angle of pitch. These are given for two different conditions: (*a*) control surfaces neutral and (*b*) elevators at an angle that reduces unstable moment to zero.

The data are taken from results of wind-tunnel tests made at the Washington Navy Yard and the Massachusetts Institute of Technology. No scale correction is applied.

The tested aerodynamic lift for balanced condition of the MC-2 hull and fins checks almost exactly with the *hydro*dynamic value. For the Shenandoah the tested value here shown is about 13 per cent high, indicating that the skin friction on the longer hull has an appreciable disturbing influence. A scale correction would tend to reduce the discrepancy.

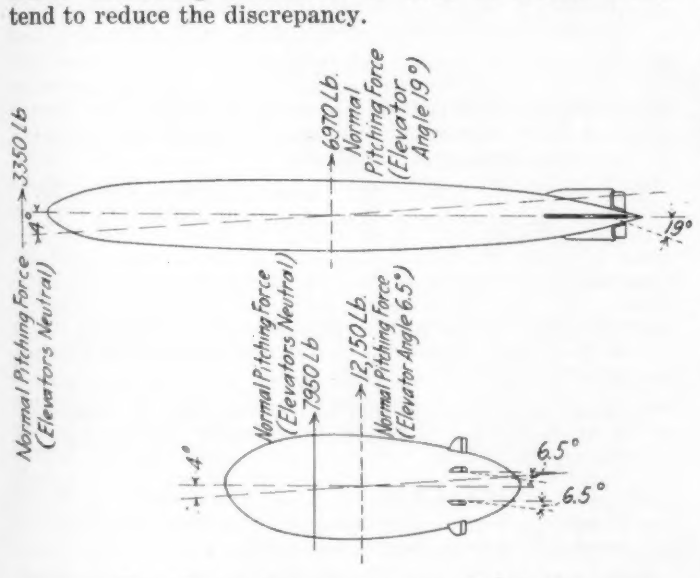


Fig. 17—Aerodynamic Stability Comparison

This Drawing Is Based on the Assumption That the Hull of the MC-2, with Fins but without the Car, Is Enlarged to Equal the Shenandoah in Volume

The diagram shows plainly why the Shenandoah and similar ships yaw and pitch *against* the wind even when moored at the very tip of the bow. Some of the geometrical characteristics are given in the accompanying table.

	Shenandoah	Metalclad
Total Envelope Surface, sq. ft.	133,400	99,500
Area of Both Sides of Side Fins and Elevators, sq. ft.	5,800	4,300
Area of Both Sides of Top and Bottom Fins and Rudders, sq. ft.	4,600	4,300
Grand Total Surface, sq. ft.	143,800	108,100
Length, ft.	678	336
Diameter, ft.	78	118
Section Modulus of Circumference, ft.^{3}	4,780	10,940

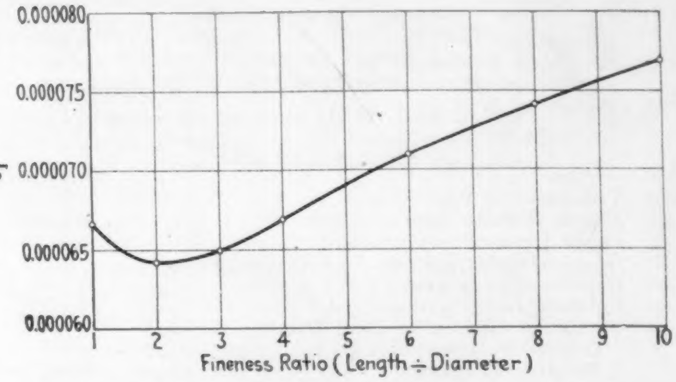


Fig. 18—Curve Showing the Comparative Frictional Resistance for Ellipsoids of Varying Fineness-Ratio

This Chart Was Developed by Integrating the Frictional Forces Due to the Actual Hydrodynamic-Velocity at Each Point on the Surface. Results Are Probably a Fair Approximation of the Total Bare-Hull Resistance for All Forms Down to a Certain Fineness-Ratio Depending upon the Details of the Hull Curve, the Reynolds' Number and Other Conditions of Use

APPENDIX 6—RESISTANCE AS AFFECTED BY FINENESS RATIO

A preponderance of evidence from many wind-tunnel tests goes to show that the resistance of a well-shaped airship hull is almost entirely frictional in character. It is, therefore, important to consider this predominant element of the resistance by itself.

Early attempts to evaluate the skin friction on an airship model were made by assuming the so-called "wetted" surface as being acted upon by an air speed equal to the speed of advance. This however ignores the fact that the actual air-speed past the surface varies all the way from zero to considerably more than the speed of advance for any one set of conditions. We have therefore developed the chart reproduced as Fig. 18 by integrating the frictional forces due to the actual hydrodynamic-velocity at each point on the surface. The effect, on the air-flow, of the frictional forces themselves is approximated by a dimensional exponent derived from wind-tunnel tests. The final formula for the frictional resistance is:

$$\text{Resistance in pounds} = c_1 V^{0.617} v^{1.83} \qquad (11)$$

where

c_1 = coefficient to be taken from Fig. 18
V = total volume in cubic feet
v = speed of advance through the air in feet per second

It is to be noted again that this formula and curve represent only an approximation of the frictional-drag alone, assuming a steady type of flow. The results are probably fair approximations of the total bare-hull resistance for all forms down to a certain fineness-ratio depending on the details of the hull curve, the Reynolds' number and other conditions of use. With the *E-H* hull curve this point comes apparently somewhere below the fineness ratio of 3. As shown by the curve, even the frictional resistance increases again at fineness ratios below 2.

APPENDIX 7—DATA ON WATER MODEL OF MC-2

This water model, which is probably the largest water model of an airship ever built will support 5125 lb. of water. It has 125 ft. of seam and 12,500 rivets of 0.055-in. diameter, all of which were put in by hand. The general characteristics of the model after final modifications and comparative data with relation to the full-size ship are given in the accompanying tables.

GENERAL CHARACTERISTICS	
Length, ft.	11.00
Maximum Diameter, ft.	3.90
Volume, cu. ft.	82.70
Weight of Hull, lb.	51.00
Fineness Ratio	2.82
COMPARATIVE DATA	
Volume	0.0004
Thickness of Plating	1.0000
Depth of Main Frame	0.1200
Other Linear Dimensions	0.0740
Gross Weight, Lift or Any Applied Force	0.3630
Relative Transverse Girder Stiffness	0.4000
Relative Longitudinal Girder Stiffness	0.0000[c]
Factor of Safety in Hull Plating for Any Given Relative Head, Including Static Bending-Moments	0.2000
Actual Pressure for Same Relative Head	67.0000

[c] Except locally.

Construction of model was begun in June, 1924, and finished in September, 1924, after air and radiation tests. The first water-inflated test was made Oct. 8, 1924. After slight modifications a second water-test was begun Oct. 20 and ran continuously until Dec. 4, 1924. A third water-test was run from Jan. 20 to 31, 1925, at the end of which period the model was finally broken down.

The tests satisfactorily demonstrated

(1) General soundness of the design
(2) Absence of severe stresses and distortion due to varying pressure
(3) Emergency means of repairing a hole
(4) No tendency for a hole to spread even in corroded sheet
(5) Complete verification of stress formulas

APPENDIX 8—GENERAL CHARACTERISTICS OF DEMONSTRATION METALCLAD UNIT MC-2

DIMENSIONS	
Hull Displacement, lb.	15,200
Hull Displacement, cu. ft.	203,000
Length of Hull, ft.	150
Breadth or Maximum Diameter, ft.	53
Height with Landing-Skid Down, ft.	66
Ballonet Volume, cu. ft.	53,000
Total Area of Fin and Control Surfaces, sq. ft.	860
Inside Length of Car, ft.	24
Inside Width of Car, ft.	8½
Inside Height of Car, ft.	6½

EXAMPLES OF USEFUL LOAD DISTRIBUTION		
Arrangement	*A*	*B*
Fuel, lb.	1,500	3,000
Oil, lb.	150	300
Ballast and Reserve, lb.	500	0
Extra Tanks, lb.	0	100
Radio, lb.	50	100
Furnishings, lb.	200	100
Supplies, lb.	200	300
Crew, lb.	500	700
Passengers or Other Load	2,000[d]	500[d]
	5,100[d]	5,100[d]

PREDICTED POWER AND PERFORMANCE		
Number of Engines		2
Total Power of Engines, hp.		400
Speed at Full Power, m.p.h.		70
Speed on One Engine Running Full Out, m.p.h.		50
Speed on One Engine at Half Throttle, m.p.h.		38
Fuel Consumption at Full Power, miles per gal.		2
Fuel Consumption with One Engine Running Full Out, miles per gal.		3
Fuel Consumption with One Engine at Half Throttle, miles per gal.		4
Ceiling at Ballonet Capacity, ft.		10,000
Rate of Climb and Descent, ft. per min.		1,000
Load Distribution	*A*	*B*
Cruising Range at Full Power, miles	500	1,000
Cruising Range with One Engine Running Full Out, miles	750	1,500
Cruising Range with One Engine at Half Throttle, miles	1,000	2,000

WEIGHTS	
Gross Lift under Standard Sea-Level Conditions with Hydrogen, lb.	13,800[d]
Gross Lift under Standard Sea-Level Conditions with Helium, lb.	12,600[d]
Weight Empty, lb.	8,700
Useful Load at Sea Level with Hydrogen, lb.	5,100[d]
Useful Load at Sea Level with Helium, lb.	3,900[d]
Useful Load at 10,000-Ft. Altitude with Hydrogen, lb.	1,100[d]
Normal Fuel Supply, gal.	250
Weight of Normal Fuel Supply, lb.	1,500

[d] Subject to a plus or minus tolerance of about 500 lb. for varying atmospheric conditions.

The foregoing figures for speeds and distances are in air miles with no allowance for the effect of winds. They also do not include the use of any hydrogen for fuel, which may be considered as a reserve equivalent to from 20 to 30 per cent more mileage.

APPENDIX 9—CONDENSED LIST OF REFERENCES

Characteristics of the Shenandoah

Air Forces, Moments and Damping on Model of Fleet Airship Shenandoah, by A. F. Zahm, R. H. Smith and F. A. Louden; National Advisory Committee for Aeronautics Report No. 215

Strength of Rigid Airships, by C. P. Burgess, J. C. Hunsaker and S. Truscott; Published in the *Journal of the Royal Aeronautical Society*, June 1924, p 327

Duralumin and Similar Alloys

Aluminum and Its Light Alloys, by Robert L. Streeter and P. V. Faragher; Published in *Mechanical Engineering*, May, 1925, p. 433

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Economics of Airship Transportation

Aerial Transportation of the Immediate Future, by R. H. Upson; Published in The Journal, June 1921, p. 593

Commercial Aspect of Airship Transport, by Major G. H. Scott; before International Air Congress, London, 1923

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Forces on Airships in Gusts, by C. P. Burgess; National Advisory Committee for Aeronautics Report No. 204

Metal Airplanes

Entwicklung und gegenwärtiger Stand des Metallflug-

zeugbaues, by C. W. Erich Meyer, Dresden; Published in *Deutsche Motor Zeitschrift*, Nos. 1 und 2, 1924

Metal Airplanes, by W. B. Stout; Published in THE JOURNAL, February, 1925, p. 209

METAL AIRSHIPS

Some Theorems in the Mechanics of High-Speed Balloons, by A. F. Zahm; before International Aeronautic Congress, 1900

(*Note*.—This report is mainly of historical value as being the first that we have on record on this subject. The theory as far as it goes is sound and formed the basis for an interesting investigation that has recently been made on the relations between gas pressure, lift, and altitude of our present design. R. H. U.)

STRESS ANALYSIS

Longitudinal Strength of Rigid Airships, by Professor William Hovgaard; before Society of Naval Architects and Marine Engineers, November, 1922

Report on the Accident to H. M. Airship R-38 by the Accidents Investigation Sub-Committee; Aeronautical Research Committee Reports and Memoranda, Nos. 775, 800 and 970

Stretching of the Fabric and the Deformation of the Envelope in Non-Rigid Balloons, by Rudolph Haas and Alexander Dietzius; National Advisory Committee for Aeronautics Report No. 16

Water-Model Tests for Semi-Rigid Airships, by L. B. Tuckerman; National Advisory Committee for Aeronautics Report No. 211

THREAD STANDARDIZATION AND RELATIVE COST

IN spite of the popularity, wisdom and economic value of standardization, some individual designers and manufacturers still have a tendency to believe their problem is the exception to the rule or else do not provide for the proper supervision of screw-thread selection. They do not seem to realize the hardships and delays that special threads impose on production and cost.

The work accomplished by the National Screw Thread Commission will help us to standardize conveniently without hardship to anyone and with decided savings to all. The investigation has been carried on in such a way, and the classifications have been presented in such a manner, that the recommendations can be followed without any changes on the part of the majority of users and producers of threaded parts. They can be advantageously followed by the small minority which still, through accident or from tradition, use special threads that can readily be changed to conform to recommended practice.

A complete system of tolerances for the different kinds of fits is provided for the different pitches. In selecting diameters it is desirable, in other than even inches, to make the fraction halves, quarters, eighths, or sixteenths. The likelihood of finding tools available will be in the order we have placed these fractions.

Complete tables are given covering the National (Briggs) taper pipe threads, straight threads, locknut threads, and firehose connection threads. In this report, therefore, we have thread specifications covering a wide range for any possible thread requirements. We cannot emphasize too strongly the importance to the Nation, from an economic standpoint, as well as the benefit to be derived in case of war, from a universal adherence to, and understanding of, the tables of thread sizes recommended therein.

Take the case of some new piece of equipment where either the designer or the draftsman accidentally, or otherwise, specifies the diameter, pitch or thread form of certain threaded parts wherein these features do not conform to anything that has been used theretofore. It might seem that such a condition would be very unlikely to arise, but it is happening every day.

The blue prints are made and preparations to manufacture are begun. When it comes to providing the threaded part, it is found that special tools are required. These are obtained at an extra expense and usually after a considerable delay. How many duplicate tools should be required for completion of the number of parts required is a question. In case enough are not ordered, production will be held up while additional quantities of the special tools are obtained. If too many tools are ordered, something will then be left over as an idle investment.

Special threads mean that both male and female gages will have to be specially made, as nothing, already in existence, can be used and considerable planning and work is involved. Suppose the interpretation of requirements is such that the tools for cutting the male and female threads result in the parts not assembling properly. Suppose the equipment, in which the special threaded parts are used, is eventually installed at a distance from where it was manufactured and that a replacement of one of these threaded parts is necessary. To duplicate them near at hand will be impossible and costly delays will result. If the threads are damaged slightly, no convenient way to re-tap or re-thread locally is available.

To manufacture chasers for cutting special threads requires special tools, taps, hobs, or hob cutters. These tools must be made up specially for the purpose. To do this, it is necessary to make special tools from which these master tools can be made.

It is surprising how many manufacturers still specify the V-form of thread. The U. S. form would be much more satisfactory. Let us stop to realize what a V-thread means. To the threading-die and tap manufacturer it is a nightmare. It not only means special tools to produce it but special tools to make the special tools. The cutters, hobs, chasers, or dies and taps all must have their turn in the hardening fire. Think of the difficulty in preserving the sharp V-points when transferred from tool to tool!

Another feature of threaded parts that deserves comment, and possibly criticism, is in the case of male threads where the draftsman shows a full thread close to a shoulder. Proper provision for necking the piece would change this requirement from a very difficult one and yet not change or affect the assembly.

Among the threads to provide a control of the movemen of two related parts we have the Acme, buttress, square, and others. It is hardly possible to attempt any standardization between diameter and pitch at the present time. However, when planning to use such threads, it is important to first get in touch with the die and tap manufacturer regarding tools that have already been produced and could meet the requirements.

To estimate that every prominent manufacturer of taps and dies carries at least 1500 specials and standards in stock and that only 200 of these sizes have a stock turnover in a year is not exaggerating. The users of such tools could simplify their own stock and reduce costs by more careful consideration of standardization and by a determination to avoid the use of special threads.

This is an age of standardization. Let us not neglect the screw threads or overlook the saving that consideration of the subject will bring about.—From an article by C. W. Bettcher in *American Machinist*.

The Construction and Equipment of a Refrigerated Laboratory

By D. M. Pierson[1]

Annual Meeting Paper

Illustrated with Photographs, Drawings and Charts

ABSTRACT

BECAUSE of the great increase in the winter use of automobiles resulting from general highway improvement and a doubling of the percentage of closed cars produced in the last 5 years, the problem of satisfactory operation of automobiles at low temperatures has assumed far greater importance than prior to 1920. It has therefore become necessary to make a more intensive investigation of the difficulties encountered in winter driving and of means for their avoidance. Study of low-temperature operation on the road is unsatisfactory because of the many variables in the conditions and the sudden and extreme changes that occur, consequently a refrigerated laboratory in which cars and engines can be tested under constant conditions that simulate as nearly as possible those met in road driving in winter is highly desirable.

By preliminary investigations it was found that driving in present closed cars is almost as comfortable at speeds up to 35 or 40 m.p.h. as driving at lesser speeds and that in many parts of the Country a car is expected to operate satisfactorily in air temperatures as low as — 20 deg. fahr. Therefore the Dodge Bros. laboratory for studying the characteristics of automobile performance at low temperatures was designed to meet these two conditions. The laboratory was built in one of the assembly buildings of the plant and consists of a cold room and equipment for reducing the temperature to — 20 deg. or lower and maintaining it at that point, apparatus for testing cars and engines and provisions for assuring the safety and health of the observers.

The walls of the cold room are built of cork-board blocks cemented together with asphalt. Refrigerator-type entrance doors, protected by a vestibule, are provided and an observation window that is made of five sheets of window glass with ½-in. air spaces between is provided for the dynamometer observer. The glass is kept free from frost and ice by calcium chloride placed at the bottom of the air spaces. Collection of frost at the doors is avoided by finishing the room inside and outside with cement plaster, which does not have the hygroscopic characteristic of lime plaster, and the room is remarkably dry at all times. This construction of the cold room results in an almost negligible transmission of heat through the walls. Communication between the inside and outside is by telephone, with numerous convenient connections within the room, and a warning signal, operated by push-buttons or automatically by accidental disconnection of the telephone, gives audible notice if the observer in the room needs help.

An ammonia refrigerating system reduces the inside temperature and absorbs a calculated total of 210,000 B.t.u. per hr. It includes an automatically controlled compressor, having a rated capacity of 49 tons when operating at 20-lb. back-pressure, and a 25-ton condenser. A blower circulates 24,000 cu. ft. of air per min. and passes the entire volume of air in the room over the cooling coils 11 times per min. The normal velocity of the air in the room is from 2½ to 3 m.p.h., but the direction of air-flow in any part of the room is controlled by louvers in a partition that separates the blower compartment from the main body of the room. The blower directs a current of cold air from the cooling coils against the radiator of a test car at a velocity of 35 m.p.h.

The room is provided with an engine test-stand and a floor-type chassis test-stand, both arranged to transmit the engine power to an electric dynamometer located outside the room. The chassis stand has four inter-connected pulleys housed in a pit for transmitting rear-wheel torque. A drain-pipe removes any collection of water from the pit and another at the lowest part of the floor proper keeps the floor dry. Exhaust gas is conducted from the engine in the chassis or on the engine-stand down through the floor and to the outer atmosphere. The crankcase breather is similarly vented to prevent dispersion of noxious gas into the room.

Air used for operation of the test-engines is admitted to the room by balanced valves in ports in the blower tunnel and is chilled to the room temperature. Provision is made, however, for warming the intake air for experimental purposes by an external heater. Fuel kept outside the room is fed to the engines as required and is measured accurately. Positive determinations of the consumption reveal transmission power-losses due to heavy lubricant, which losses heretofore have been attributed solely to faulty carburetion.

Some characteristics of the cold room are as yet unknown, but it is believed that the temperature of the room and of a 3000-lb. automobile in it can be reduced from 70 to — 20 deg. fahr. in 4 hr. and also that it will be possible to reduce the temperature to — 50 deg. fahr. with the equipment provided. As such a low temperature cannot be measured by a mercury or spirit thermometer, owing to the freezing of mercury at — 39 deg. and the separating of the indicating column in a spirit instrument, experiments are being made in the recording of temperatures at various locations in the room with a Leeds & Northrup recorder and thermocouples.

This refrigerated laboratory is thought to be complete in every detail for all necessary investigations of low-temperature automobile operation, such as starting and warming-up characteristics of the engine, discharge capabilities of storage-batteries, channeling of gear lubricants, crankcase-oil dilution and the collection of water in the crankcase, effects of sudden temperature-changes on body finishes, and carburetion and fuel-mixture distribution.

IMPORTANCE of the successful and satisfactory operation of automobiles at low temperatures has assumed far greater proportions in recent years than formerly, as, up to the year 1920, the prime consideration, almost to the exclusion of other considerations, was proper carburetion with the engine warm. From 1921 to 1925 the percentage of closed cars to the total number of passenger automobiles produced in the United States more than doubled, as shown by Fig. 1, the figures for which were supplied by the National Automobile Chamber of Commerce. This great increase in closed cars is conclusive evidence that more persons are using their

[1] M.S.A.E.—Experimental engineer, Dodge Bros., Detroit.

cars during seasons that in the past were very undesirable for driving. Improvement in highways in all parts of the Country has, like the closed body, been a great incentive to year-round driving.

The difficulties experienced in cold-weather operation of cars assumed greater importance with the increase in the number of cars driven during the winter months and it became necessary to make a more intensive investigation of these difficulties and of means for their avoidance or correction. Personal experience proves that the study of low-temperature operating-conditions on the road is very unsatisfactory because of the many variables that enter into road operation and because of the extreme changes in temperature experienced in short periods in regions where low temperatures occur.

Test Room Gives —20-Deg. Fahr. Conditions

Closed automobiles of the present have standard equipment or added accessories that make cold-weather driving, up to 35 or 40 m.p.h., almost as comfortable as driving in more moderate temperatures. Therefore, in planning a laboratory and equipment for studying the characteristics of automobile performance at low temperatures, it was regarded as necessary to maintain a constant temperature while the car was operating with a power development equivalent to the load imposed by a road speed up to at least 35 m.p.h. Moreover, it had been found that, in many parts of the Country, successful automobile performance at temperatures as low as — 20 deg. fahr. is expected. With these two conditions determined upon, the designing of the refrigerated test-room at the Dodge Bros. plant was begun. The final design was the result of eight previous plans that were discussed and rejected.

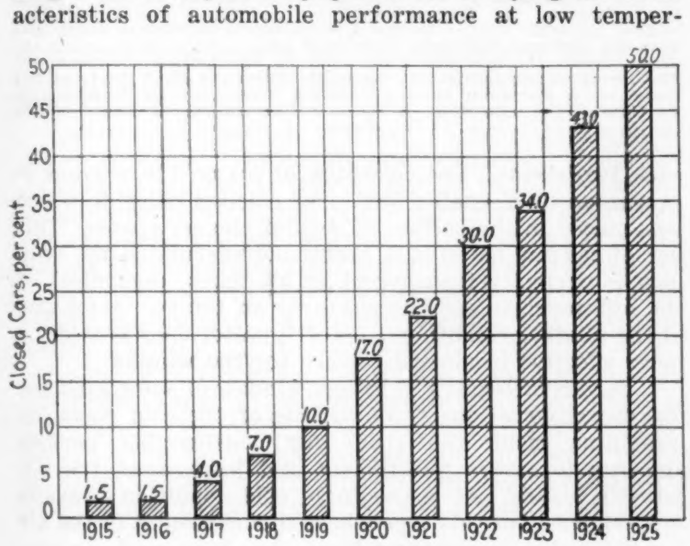


Fig. 1—Increase in Percentage of Closed Cars to Total Passenger-Car Production

The Percentage More Than Doubled from 1920 to 1925 and Half of the Cars Produced Last Year Were of Closed Types. These Facts Are Regarded as Conclusive Evidence of a Great Increase in Winter Driving

The most convenient arrangement in the plant environment was to build a separate room in one of the assembly buildings to house the entire low-temperature laboratory, which consists of the cold room equipped with an electric absorption-dynamometer of the cradle type, as shown in Fig. 2, an ammonia-gas compressor, shown in Fig. 3, and all of the appurtenances of the compressor.

Heat Absorption of 210,000 B.t.u. Per Hr.

The essential feature of any low-temperature laboratory is the cold room, and the ability of the structure to insulate thermally the inner from the outer atmosphere measures the success or failure of the entire installation. In our installation the loss of heat through the insulated walls is almost negligible as compared with the total heat absorption required. A heat absorption of 210,000 B.t.u. per hr. was necessary, as determined by calculations, to maintain a temperature of — 20 deg. fahr. This total quantity of heat was the calculated sum of the heat dissipated by an engine developing 10 b.hp. at a speed equivalent to 35 m.p.h., two observers in the room, and the electric lights; heat introduced by air admission through doors, observation window and insulation, and

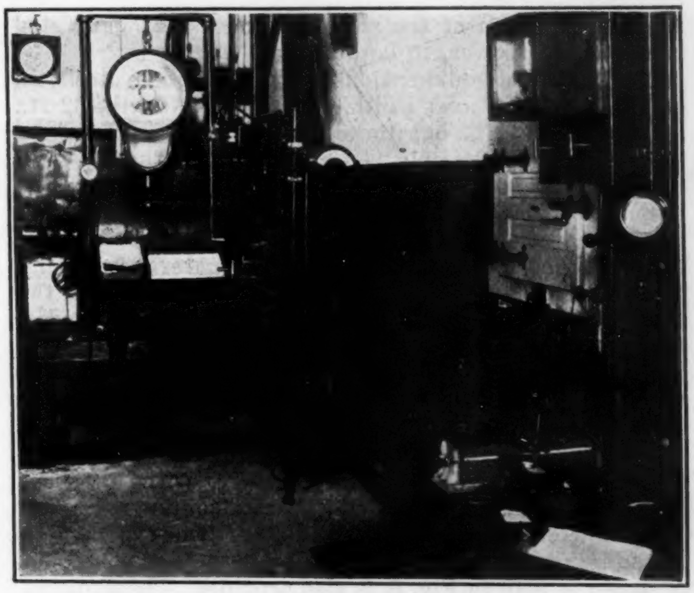


Fig. 2—Electric Absorption-Dynamometer Located Outside of the Cold Room

The Cold Room on the Right Has an Observation Window That Is Closed by a Refrigerator Door. The Dynamometer Is in Line with the Engine Test-Stand Inside the Room and the Test-Engine Is Coupled through a Universal-Joint Directly with the Dynamometer Shaft. A Silent Chain Connects the Dynamometer Armature-Shaft with the Shaft of the Floor-Type Chassis Test-Stand. Thus One Dynamometer Serves for Testing Separate Engines or Chassis Rear-Wheel Torque

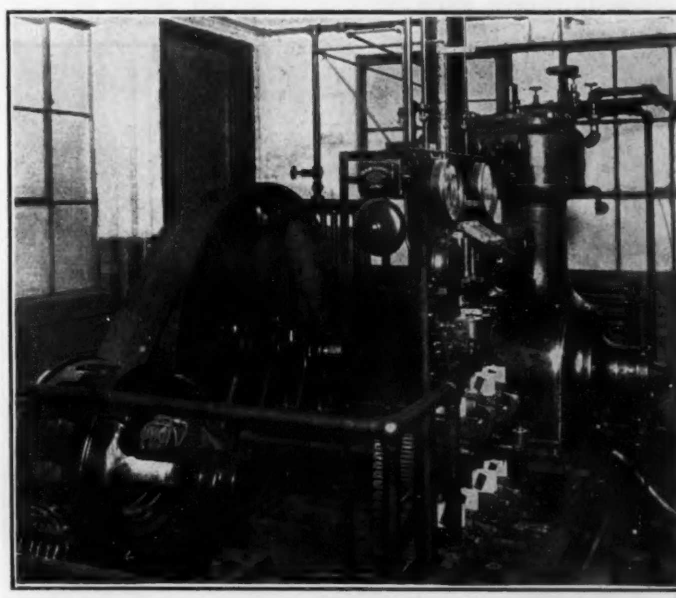


Fig. 3—Electric-Driven Ammonia-Gas Compressor

This Is a Two-Cylinder Single-Acting Closed-Type Machine of 10-In. Bore and 10-In. Stroke and Is Driven by a 50-Hp. 440-Volt Slip-Ring Motor Operated at 900 R.P.M. The Compressor Speed Is 220 R.P.M. It Has a Refrigerating Capacity of 49 Tons Per 24 Hr. When Operated at 20-Lb. Back-Pressure

for the operation of the engine; and of heat generated by a Sirocco blower, to be described later.

The total inside dimensions of the cold room itself, as shown in Fig. 4, are: width, 11 ft. 6 in.; length, 32 ft., and height, 14 ft., but the actual available laboratory space in the room is only 11 ft. 6 in. wide, 7 ft. 1 in. high in the clear, and 25 ft. long. The rest of the space in the room is occupied by cooling coils and an air-circulating fan. The walls of the room are of Crescent cork-board and are 8 in. thick at all places. This material was supplied in blocks approximately 24 x 30 x 4 in. in size for ease of handling, and asphalt was used as a binder, wooden skewers being employed to hold the blocks together until the binder cooled and set.

Engine and Chassis Test-Stands

The room is provided with a stand on which an engine can be set-up and operated separately, with its shaft connected directly through universal-joints with the dynamometer shaft, as in Fig. 5. A floor-type power transmission to the armature shaft of the dynamometer, as shown in plan in Fig. 6, is also provided. The dynamometer is located outside of the cold room. Exhaust gas from the engine, whether the engine is on the stand or in a car on the floor, is carried down through the floor and emitted to the atmosphere. A vent from the crankcase breather to the outer atmosphere is also provided, as a highly noxious gas is often liberated from the breather.

Provision is made for draining water from the floor at two places, one of which is in the pit that houses the chassis-dynamometer pulleys. The other outlet is at the lowest place in the floor proper. It is necessary to provide for this water drainage because, if the temperature of the room is raised quickly to the temperature of the outside atmosphere by opening the doors to the outside air, any frost that may form on the cooling coils will melt and result in an excessive collection of water in the room.

An observation window, placed in the wall of the room at a location that is convenient for the dynamometer operator, is 26 in. square and composed of five sheets of single-thickness glass with a ½-in. air space between

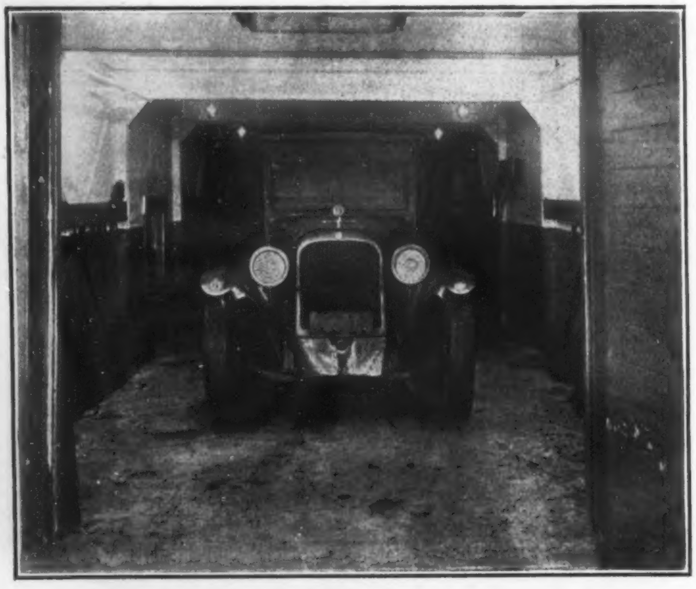


Fig. 4—Interior of Cold Room Looking through Entrance Doors Toward Blower Compartment

The Test Car Is Anchored in Position on the Floor-Type Chassis Dynamometer. The Observation Window for the Observer at the Electric Dynamometer Outside the Room Is Seen on the Left

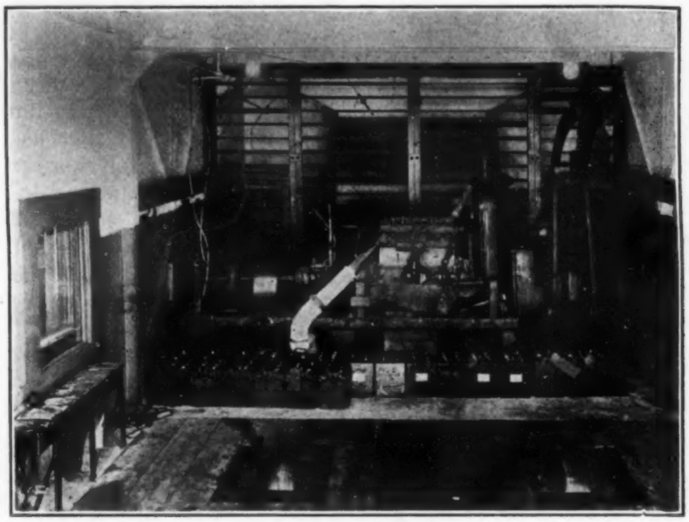


Fig. 5—Blower End of Cold Room

In the Immediate Foreground Are the Pulleys of the Chassis Dynamometer. An Engine Is Shown on the Test-Stand in the Middle Ground Coupled to the Dynamometer Armature-Shaft and with the Exhaust-Manifold Connected with a Pipe That Leads the Gases Down through the Floor and to the Outside Atmosphere. The Blower Compartment Is Separated from the Main Body of the Room by a Partition Having Louvers That Can Be Manipulated To Control the Direction of the Air Current in All Parts of the Room

each two sheets. The collection of ice on the window is prevented by a small quantity of calcium chloride which was placed in the bottom of each of the air spaces. This use of calcium chloride is highly successful and the window is perfectly transparent at all times, regardless of the difference in air temperatures on the two sides and of the weather conditions. A refrigerator door provides a more effective insulating closure for the window.

It is very necessary to have a window of some kind for making observations from outside of the cold room, as remaining inside the room for considerable periods amounts to severe punishment and jeopardizes the observer's health. An exceedingly cold condition prevails in a cold room of this type where the movement of the air is appreciable, hence an endeavor has been made to protect the health of the observers by providing aviators' complete uniforms and insisting upon their use when inside the room.

Telephone communication between the inside and outside of the room is provided, with jacks placed at convenient locations. Push-type electric-light switches inside the room control a warning signal outside by which an observer in the room can call for help if necessary. As a further precaution, the telephone jacks are interconnected with this signal circuit so that warning is given whenever the telephone plug is disconnected from the jack. Thus, should the observer be overcome from any cause and fall, the telephone plug would be pulled from the jack and a warning signal sounded.

How Engine Air and Fuel Are Controlled

Air for the operation of the test-engine is drawn into the room through two ports that enter directly into the inlet side of a blower and have balanced valves. This arrangement makes it possible to chill all incoming air to the temperature of the cold room before it is used, but provision is also made for warming the carbureter air by an external heater to any desired temperature for experimental investigation. A fact of interest is that no trouble has been occasioned by excessive collection of frost on the cooling coils, which might be expected as the result of freezing of the moisture in the incoming air.

The supply of fuel for the engines is kept outside of the cold room proper and is fed as required. The gasoline system includes equipment for the very accurate measuring of the fuel used. This makes possible positive determinations, measured in miles per gallon of gasoline consumption, of transmission power-losses due to heavy lubricant, which losses have been charged in the past entirely to faulty carburetion.

Compressed-air pipes were led into the room, although the use of compressed air may be very limited. Two additional automatic balanced valves were placed in the walls of the room to protect the cork walls against possible damage should there be any valve leakage from the compressed-air line, with resultant creation of appreciable pressure within the room.

Air Kept Dry at All Times

Use of only cement plaster for both inside and outside surfacing has afforded complete relief from the pronounced inconvenience caused in a majority of cold rooms by the collection of frost or ice at all of the refrigerator doors, and the room is surprisingly dry at all times. The collecting and congealing of moisture in most cold rooms is caused by the hygroscopic characteristic of the lime in ordinary plaster which attracts or condenses moisture from the air.

Provision is made in the floor of the cold room, as shown in Fig. 7, for solidly anchoring the car against forward movement, so that, in case of sudden brake application while the engine is driving through the chassis dynamometer, the car will not move. Upon using the chassis dynamometer, it was found that the car exhibited a slight tendency to float sidewise on the pulleys, and it became necessary to tie the car to resist this movement also.

An entry vestibule 4 x 6 x 8 ft. was built so that the minimum change in temperature would occur while an observer was entering or leaving the cold room. Our experience so far has shown that the temperature in this vestibule remains at very nearly the mean between the temperature of the refrigerated room and that of the outside atmosphere. This vestibule is regarded as very desirable.

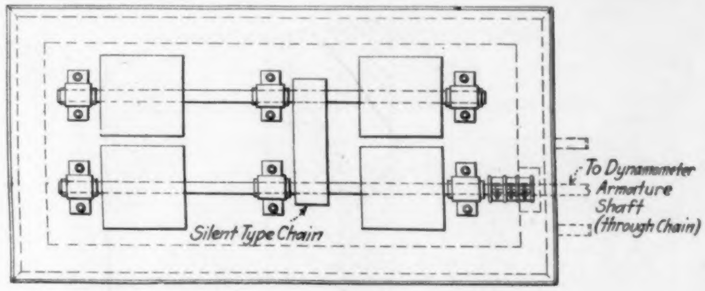


Fig. 6—Plan of Floor-Type Power Transmission
This Is Located in a Pit and the Two Pairs of 18-In. Pulleys Are Mounted on Parallel Shafts Which Are Interconnected by a 7-In. Silent Chain. One Shaft Is Coupled at the Right to the Electric-Dynamometer Shaft by a Silent Chain

Large refrigerator-type doors were placed in the end of the test room to afford a 7 x 7-ft. opening through which the cars and engines or other units to be investigated can be taken.

Air Chilled by Ammonia Cooling-Coils

Actual refrigeration in the cold room is effected by the passage of air over the cooling coils shown in Fig. 7. These coils consist of 7200 running ft. of $1\frac{1}{4}$-in. extra-heavy ammonia pipe and are connected in the conventional form by a wet header on the inlet end and a dry header on the suction end. To prevent any dripping from these coils upon the car or engine while operating and also to complete the air tunnel about the coils, a drip pan was built-in as shown. It is of a double thickness of tongued and grooved ceiling lumber, with heavy building-paper between, and the top surface is covered with galvanized iron. This type of drip pan was used to keep the room still drier.

As a serious leakage of ammonia would cause a most dangerous condition, extreme care was taken in the design of the room to avoid any disturbance of the coils in event of an accident within the room. Avoidance of this

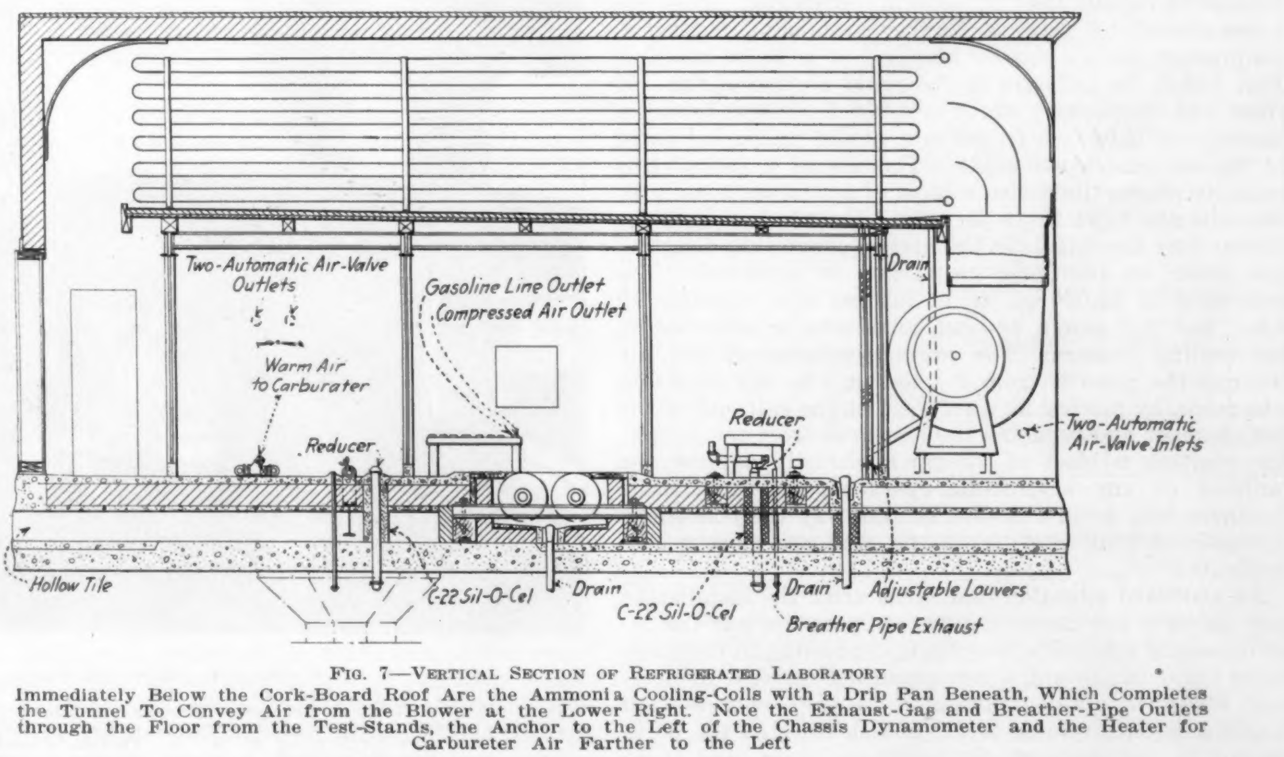


Fig. 7—Vertical Section of Refrigerated Laboratory
Immediately Below the Cork-Board Roof Are the Ammonia Cooling-Coils with a Drip Pan Beneath, Which Completes the Tunnel To Convey Air from the Blower at the Lower Right. Note the Exhaust-Gas and Breather-Pipe Outlets through the Floor from the Test-Stands, the Anchor to the Left of the Chassis Dynamometer and the Heater for Carbureter Air Farther to the Left

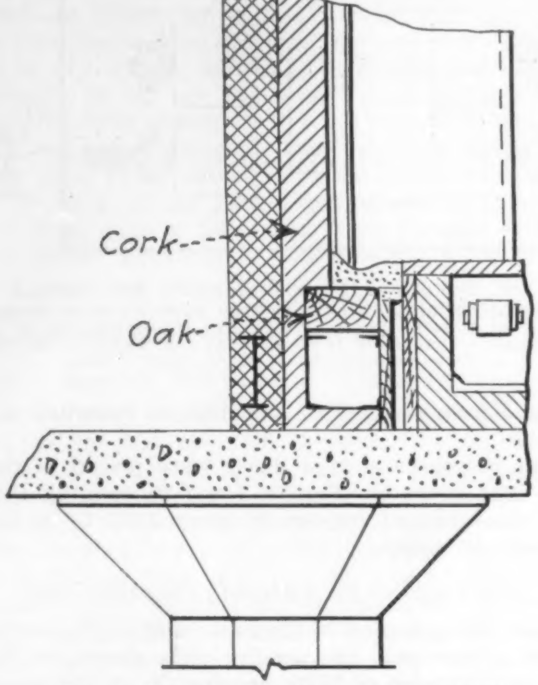


FIG. 8—HEAT-INSULATION OF COIL SUPPORT
The Steel Framework Is Supported on Non-Conducting Oak Beams That Are Insulated from the Floor by Air Space and Cork Blocks

possibility was made more positive by mounting the coils on a self-sustaining steel structure that is independent of the cold-room walls. A rather interesting feature of this particular installation that is worthy of note is the care that must be taken to insulate it against heat loss through the steel framework, as shown in detail in Fig. 8.

BLOWER MOVES ENTIRE AIR VOLUME RAPIDLY

Because of the comparatively rapid dissipation of heat into the cold room, some provision was necessary to pass the entire volume of air in the room over the cooling coils more rapidly than by natural circulation. This was accomplished by using a Bunker system of cooling in conjunction with a fan or blower. It is to be noted in Fig. 7 that the coils are in the upper section of the cold room and the blower, which is a No. 7 Sirocco having a capacity of 24,000 cu. ft. per min. at 320 r.p.m., is located at the extreme lower right. The use of a fan of this capacity passes the entire volume of air in the room over the coils nearly 11 times per min. The air-flow from the blower over the coils is in the normal convection direction and hence no additional restriction is presented. The movement of 24,000 cu. ft. of air per min. requires 10 b.hp., and this power, as heat, must also be absorbed by the cooling system. The normal velocity of the air through the room is from 2½ to 3 m.p.h., but provision was made, by placing an air-funnel at the exit end of the coil chamber and reducing the exit area from the blower, for creating a blast of 35 m.p.h. directly against the radiator of any automobile operating on the chassis dynamometer, as in Fig. 9. In this way the conditions encountered while driving on the road are more nearly duplicated.

An awkward situation that arose after the installation was complete and the laboratory in operation was the development of a slight atmospheric depression in the room below the drip pan and a corresponding increase of pressure above it. This depression in the lower section caused a minute volume of air to leak through the wire-conduit to the switches and telephone jacks, and these units became frozen and inoperative after a short period of operation. The difficulty was remedied, after considerable experimenting, by separating the switches and jacks from the conduit and mounting them on panels in the room.

To secure a more nearly equal distribution of the air over the entire coil unit, deflectors were mounted in the exhaust side of the blower, as shown in Fig. 10. Direction of the air currents in the room is controlled by the opening or closing of louvers in the partition that separates the cold room proper from the blower chamber.

POWER-ABSORPTION AND INDICATING APPARATUS

The means of power absorption when operating a car in the cold room is by power transmission from the rear wheels through four 18-in. pulleys mounted on two parallel shafts each of which is carried on three ball-bearing shaft-hangers, as in Fig. 6. The shafts are connected together by a silent chain of 7-in. width to assure each of the four pulleys absorbing its own share of the rear-wheel torque. Four pulleys were used instead of two to afford less unit deflection of the tires and eliminate tire failure on the chassis dynamometer as much as possible. It was necessary to assure maximum insulation of positive heat on this unit of the installation also, and it will be observed by Fig. 11 how this was accomplished by mounting the pulley supports on oak beams and surrounding the pulley pit with cork-board blocks.

The electric dynamometer was placed in line with the engine-stand and a silent chain was used to connect the electric-dynamometer armature-shaft with the chassis-dynamometer shaft, thus making possible the use of a single dynamometer for power absorption, although this practice precludes the possibility of using the engine-stand and the chassis-stand at the same time.

The cooling medium in this installation is ammonia,

FIG. 9—AIR-BLAST DIRECTED AGAINST RADIATOR
An Air-Tunnel at the Exit End of the Cooling-Coil Chamber Terminates in a Reduced Area and Enables the Blower To Send a Frigid Current against the Radiator of a Car on the Chassis Dynamometer at a Velocity of 35 M.P.H., Thereby Closely Simulating Conditions Encountered in Winter Driving on the Road

which is believed to be the only liquid that can be used successfully when large refrigeration capacities are required. The theory of the cooling characteristics in this installation is the same as that of any mechanical refrigerating installation, that is, that heat is absorbed from the surrounding medium by the expansion of a liquefied gas. In the process of liquefaction of ammonia gas, the gas is first compressed to a rather high pressure, then cooled in some type of condenser to a liquid and transferred from the condenser to a receiving drum. The liquid ammonia is drawn from this drum to the direct-expansion or cooling coils, where, due to the lower pressure than exists in the receiver, the released ammonia boils. The effect of pressure on the boiling temperature

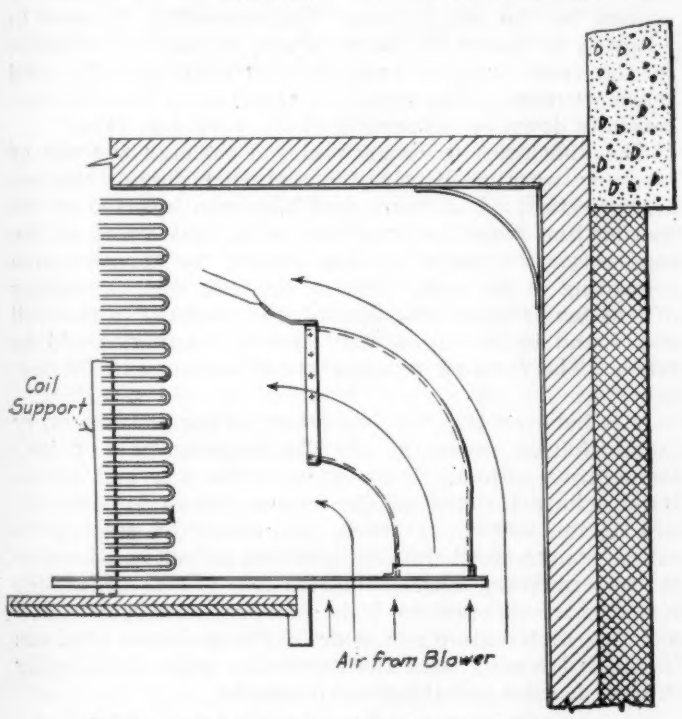


FIG. 10—DETAIL OF BLOWER-DISCHARGE DEFLECTORS
Deflectors Are Provided on the Exhaust Side of the Blower To Assure More Nearly Uniform Distribution of the Air Current over the Entire Cooling-Coil Unit

of the liquid ammonia is the same as on any other liquid, that is, the boiling temperature is lowered as the pressure is decreased. This is shown clearly in Fig. 12. The amount of heat absorption, naturally, is directly proportionate to the capacity of the compressor and condenser to liquefy the gas.

DETAILS OF COMPRESSOR AND CONDENSER

In the installation that is under discussion the compressor, which is shown in Fig. 3, is a two-cylinder vertical single-acting closed-type machine of 10-in. bore and 10-in. stroke. It is belt driven by a 50-hp. 440-volt slip-ring electric motor, operating at 900 r.p.m. The slip-ring type of motor is necessary in all cases where automatic control is desired. The pulley diameters are such as to give a compressor speed of 220 r.p.m. In the drive is inserted a Lenox idler, which is believed to be highly desirable in any installation similar in its full-automatic characteristic to that here described. The control of the compressor is fully automatic both for temperature uniformity in the cold room and for protection of the entire installation. By full-automatic control is meant a low-voltage and overload release, thermostatic temperature-control by a Taylor low-temperature thermostat through dash-potted starting relays, low-water-pressure release

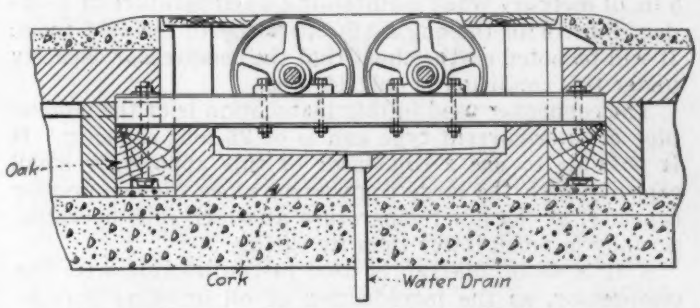


FIG. 11—VERTICAL SECTION OF CHASSIS DYNAMOMETER
Wheel-Torque Pulleys Are Mounted in a Pit with Their Supports Resting on Oak Timbers. The Timbers and Entire Pit Are Heat-Insulated with Cork

relay and excessive-condenser-pressure release relay. A warning bell is sounded, however, before the excessive-pressure relay functions, so that one has an opportunity to correct any difficulty before the machine shuts-down automatically, provided an attendant is present.

Lubrication of the compressor is by pressure feed, at about 25 lb. per sq. in., to the main bearings and by a directed oil-stream against the pistons and piston-pins. The valves are of the automatic poppet type. A safety head is provided because the introduction of liquid ammonia into the compression-chamber probably would wreck some part of the machine, as it has a very slight clearance volume, which, if considered in terms of the compression-ratio of an internal-combustion engine, would be a ratio of about 330 to 1. A compressor of this size, operating at 220 r.p.m., gives a rated capacity of 49 tons when operating at 20-lb. back-pressure.

By Fig. 12 it will be seen that the back-pressure must be appreciably lower than 20 lb. to maintain a temperature of — 20 deg. fahr. in the cold room. It must also be taken into account that the temperature, as shown on the chart, is that within the coil itself at the various back-pressures and that the difference between this value and the actual temperature within the room would be appreciable. We have found by test that it is necessary to operate the machine at a back-pressure of approximately

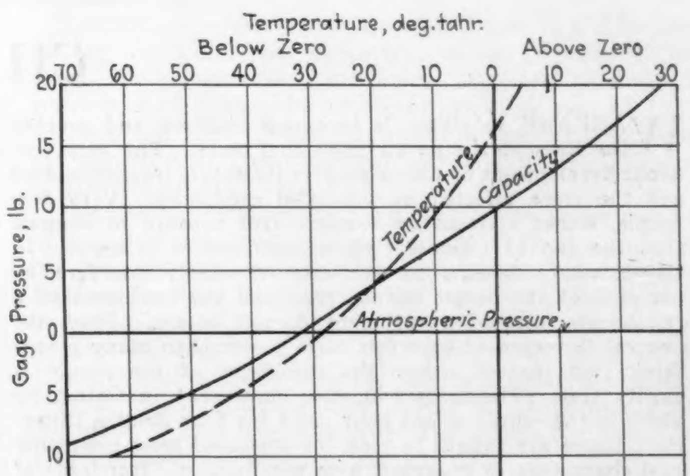


FIG. 12—CHARACTERISTICS OF AMMONIA COMPRESSOR
The Ammonia Boiling-Temperature and the Refrigerating Capacity of the Compressor Decrease as the Back-Pressure Decreases. By Test It Has Been Found Necessary To Operate the Compressor at a Back-Pressure of 5 In. of Mercury To Maintain a Temperature of — 20 Deg. Fahr. with the Engine in Operation in the Cold Room. Under This Condition the Capacity Is Only 15 Tons of Refrigeration in 24 Hr., Although the Rated Capacity at 20-Lb. Back-Pressure Is 49 Tons

5 in. of mercury when maintaining a temperature of — 20 deg. fahr. with the engine in operation in the cold room. It will be noted on the chart that the compressor capacity under this condition is only 15 tons.

The condenser used in this installation is of the double-pipe counter-current type and is of 25-tons capacity. It is possible to use a condenser of this apparently small capacity with the large compressor since the compressor capacity, at the low temperature at which it is operated, actually is much lower than its rating.

A 12 x 48-in. oil-trap is used in conjunction with the compressor, as the introduction of oil or other foreign matter into either the condenser or the cooling coils robs the system of its efficiency. The ammonia receiver is a steel drum of 24-in. diameter and 9 ft. long, which is provided with a safety valve to release excessive pressure, should any prevail, into the outside atmosphere. The ammonia from the receiver is fed to the cooling coils by an automatic expansion-valve. Approximately 1100 lb. of the liquid is used in the system.

After installation and test, it was found that an excessive quantity of liquid ammonia was being drawn from the expansion coils back to the compressor and it was imperative to reduce the quantity of liquid ammonia fed to the coils. In reducing the flow of ammonia through the expansion valve to a point where the return of liquid to the compressor stopped, the compressor capacity was reduced to such an extent that the minimum temperature could not be maintained. This difficulty was overcome by introducing an ammonia-trap in the suction line, allowing all trapped liquid to drain back into an isolated coil in the cold room, and pumping off only the liquid.

Temperature of — 50 Deg. Fahr. Believed Possible

As the laboratory is new and has been in continuous use, since completion, for running tests of cars and engines, some of its characteristics, aside from those present under the conditions of the tests, are not now known. For example, the minimum time required to lower the temperature of the room together with that of some additional mass of material, such as a car or engine, from normal to any predetermined value, is unknown. It is assumed, however, that the temperature of the room and of a 3000-lb. automobile, can be lowered from 70 to — 20 deg. fahr. in 4 hr. Also, the lowest possible temperature that can be obtained is problematical. However, a vacuum on the cooling coils of 20 in. of mercury has been drawn and maintained. As indicated by Fig. 12, the temperature within the expansion coils, under this condition, would be — 64 deg. fahr., hence a temperature somewhat lower than — 50 deg. fahr. is expected.

The measurement of such low temperatures has introduced some additional problems, as both spirit and mercury thermometers seem to be very erratic in performance. Two readily recognized conditions were the freezing of the mercury and the separating of the indicating column in the spirit type. Experimenting is now in progress to record the temperatures at various locations in the room with a Leeds & Northrup recorder and thermocouples. This system is expected to function successfully down to temperatures of — 60 deg. fahr.

The difficulties to be encountered through the use of mercury were positively demonstrated during the acceptance test. A mercury well had been inserted in the suction line from the expansion coils, just ahead of the compressor, to study to some extent the temperatures prevailing in the coils. During the test, when a reading of this temperature was desired, the mercury in the well was found to be frozen solid and no readings could be taken. The freezing temperature of mercury is -39 deg. fahr.

It is believed that the laboratory is complete in every detail that is necessary for the investigation of low-temperature automobile operation. Starting and warming-up characteristics of the engine, discharge capabilities of the storage-batteries, channeling of gear lubricants, crankcase-oil dilution and the collection of water in the crankcase, chassis lubrication, effects of sudden temperature-changes on body finishes, and carburetion and fuel distribution are some of the problems that can be studied readily with the respective units functioning in their normal operating environments.

CHINA

WARFARE in China is becoming civilized and touches the lives of the people more and more. The very economic development of China renders its people interdependent and the more affected by unsettled conditions. Very few people, either Chinese or foreign, will venture to suggest that the end of Chinese civil disturbance is in sight. In China, where foreign Governments repeatedly interfere, 80 per cent of the people cannot read and the traditions of a republican form of government do not obtain. True, the Central Government exercises more power than many people think; but that it enjoys the confidence of the people is hardly true. The mass education movement in China, by which in the course of one hour daily for four months illiterate Chinese are taught to read the thousand most commonly used characters, is pregnant with possibilities. Hundreds of thousands of Chinese have already learned to read as a result of this movement, and that millions will profit by the opportunity is within the limits of possibility.

No student of American commercial development or international commerce can fail to have anything but the utmost confidence in the ultimate development of the Orient. With our exports showing a decreasing percentage of raw materials and an increasing percentage of manufactured commodities, and our import figures revealing the opposite tendency, the significance of Asia as a source of raw materials and a market for manufactured articles needs no emphasis. The possible development of the Far East through the course of years staggers the imagination. There can be no question as to what it means to the United States of America. It is imperative that men interested in business, men interested in national welfare, turn their serious attention to what is likely to happen in the Orient. We should remember that what happens there does not depend solely on what happens on that side of the water, but also on what happens here, now and with us. It is extremely important that we learn the real facts, that we insist that our representatives keep in touch with the real situation.—H. T. Lewis in *American Bankers Association Journal.*

Officers of the Society

AT the Annual Meeting of the Society held last month a President, a First Vice-President, five Second Vice-Presidents representing motor-car, tractor, aeronautic, marine and stationary internal-combustion engineering respectively and three Councilors were elected and the Treasurer was reelected. In addition to these officers the three Councilors elected at the 1925 Annual Meeting and the last Past-President are voting members of the Council for 1926. In accordance with the usual custom photographs of the members of the Council are presented on the following pages and their careers are outlined below.

T. J. Lítle, Jr.

President Lítle was born in Philadelphia and was educated at the public schools of that city, the Manual Training High School, the Industrial Art School, and the University of Pennsylvania. He began his business as a contractor, installing isolated electric lighting and powerplants.

Later, he formed a company to market a high-powered self-intensified gas-lamp. This gas-lamp contained a supercharger that was driven by a motor device of a type identically like the one now used on internal-combustion engines, the motor receiving its energy from the waste heat of the lamp itself. This lamp proved to be the most powerful illuminant of that period. His company, as well as his numerous patents, was taken over by the Welsbach Light Co., Gloucester City, N. J., Mr. Lítle becoming chief engineer of the Welsbach Company. During the few years that he held this position Mr. Lítle was credited with over 100 inventions. For his researches and development work in gaseous combustion, he was granted a gold medal at the Panama-Pacific Exposition of San Francisco. For a long time, Mr. Lítle was actively interested in the American Gas Institute and the National Commercial Gas Light Association and was one of the founders of the Illuminating Engineering Society.

His connection with the automotive industry dates back to 1917 when he became associated with the engineering department of the Cadillac Motor Car Co. In a few months he advanced to the position of research and experimental engineer and in 1918 he joined the engineering staff of the Lincoln Motor Co. in that same capacity. Subsequently, Mr. Lítle was made chief engineer, a position that he still holds.

On March 8, 1919, he was elected to Member Grade in the Society. Since that time, he has taken a very prominent part in the activities of the parent society as well as of the Detroit Section. For the administrative year 1923, Mr. Lítle was a member of the Meetings Committee, and for the last 2 years, he has served as its chairman. Besides, he served on the Research and Hardwood Lumber Standardization Committees of the Society, and on the Motor Vehicle Lighting Specifications Sectional Committee of the American Engineering Standards Committee for 1924. At the 1925 Annual Meeting Mr. Lítle was elected First Vice-President. For the year beginning May, 1922, he was Secretary of the Detroit Section and the following spring, was elected Chairman of the Section. In the fall of 1923, at a meeting of the Indiana Section, he presented a paper entitled Spring Movement and Vibration Study of Cars in Action. In this paper, Mr. Lítle outlined in a most interesting manner some of the methods used to record the movement of the springs of cars as well as the nature and amplitude of the various vibrations. He has lectured before the Taylor Society and the engineering school of the University of Michigan. On several occasions, he has written articles for the automotive press. The principal subject of his articles has been the desirability of perpetuating a fundamentally good design and then augmenting it by refinements that would be completely interchangeable with the old parts.

J. H. Hunt

First Vice-President Hunt was born at Saranac, Mich., on March 24, 1882. He received his technical education at the University of Michigan, being graduated from that institution in 1905 with the degree of bachelor of science in electrical engineering.

After graduation Mr. Hunt went with the Western Electric Co., first in the power apparatus apprentice department and later in the engineering department. Entering educational work, a year was spent in the department of electrical engineering at Washington University and 5 years with the electrical engineering department at the Ohio State University. Mr. Hunt entered the engineering department of the Packard Motor Car Co. in 1912, concentrating on the application of electrical equipment. In 1913 he became research engineer for the Dayton Engineering Laboratories, working on all problems of electrical installations on motor cars with special attention to ignition. From 1920 until last summer he was head of the electrical division of General Motors Research Corporation, Dayton, Ohio. When the Corporation became the General Motors Corporation Research Laboratories, Mr. Hunt was transferred to Detroit where he holds a position similar to that which he had at Dayton.

Mr. Hunt was elected to Member Grade in the Society on Jan. 14, 1916. He was active in the Dayton Section from its organization, until his transfer to Detroit, serving as Chairman for the administrative year of 1922. In 1924 and 1925 he was Chairman of the Sections Committee and also Vice-Chairman of the Lighting Division of the Standards Committee.

Heavy-Fuel Carbureter-Type Engine was the subject of a paper presented by Mr. Hunt in 1919 at a meeting of the Metropolitan Section. In 1920 he described Battery-Ignition Systems before the Cleveland Section, and Science and Engineering was his topic at a meeting of the Indiana Section. In collaboration with G. F. Embshoff, also of the General Motors Research Corporation, a paper on Some New Electrical Instruments for Automotive Research was presented before the Cleveland and the Indiana Sections last spring.

G. W. Smith

Second Vice-President Smith representing motor-car engineering was born at Foxburg, Pa., on Nov. 4, 1881. His education was obtained at the grade schools of his birthplace and the Westinghouse Technical Night School where he studied for 3 years.

From 1898 to 1900 Mr. Smith was employed in the factory of the Westinghouse Electric & Mfg. Co., East

Pittsburgh, Pa., being transferred to the engineering department as detail draftsman in 1900. In 1902 he was sent abroad to the Manchester, England, plant of the British Westinghouse Electric & Mfg. Co., where he was engaged in detail and tool drafting until the following year when he was appointed assistant superintendent of maintenance. Returning to this country in 1904, Mr. Smith was appointed tool designer for the Westinghouse Air Brake Co., Wilmerding, Pa., a position that he held for 4 years. From 1908 to 1913 he was engaged in experimental automobile work for H. H. Westinghouse at the Wilmerding plant. This consisted principally of developing a special transmission for automobiles, motor trucks and gasoline locomotives. In 1913 Mr. Smith accepted a position as engineer and chief draftsman with the Thomas B. Jeffry Co., Kenosha, Wis., and designed the Jeffry Quad truck. The following year he was appointed chief engineer of the company and remained there until 1917 when he entered government work as consulting engineer with the Ordnance Department in connection with the building of the Nash Quad trucks. In 1918 he was appointed chief of the inspection division for the Director of Purchases of the Army and was assigned to the Detroit District. Upon being discharged from the government service in 1919 Mr. Smith was appointed chief engineer of the Milwaukee division of the Nash Motors Co., a position that he still holds.

Mr. Smith was elected to Member Grade in the Society on Nov. 24, 1913. He served on the Truck Standards Division of the Standards Committee in 1918 and 1919 and was a member of the Passenger Car Division last year. Mr. Smith was Chairman of the Mid-West (now the Chicago) Section in 1918 and served as Vice-Chairman of that Section the following year. When the Milwaukee Section was formed in 1924 Mr. Smith was elected its Chairman and last year was Vice-Chairman of the Section.

Oscar W. Sjogren

Second Vice-President Sjogren, representing tractor engineering was born in Hildreth, Neb., on Aug. 15, 1887. He received his elementary school education in a country school in Phelps County, Neb., and his high school education in the school of agriculture of the University of Nebraska at Lincoln. He entered the engineering college of the University in the fall of 1909. In addition to studying he also acted as instructor in forge work and farm machinery. He was graduated from the University in 1915 with the degree of bachelor of science in agricultural engineering and returned in September of that year as an instructor in agricultural engineering. The following year he was promoted to assistant professor and became an associate professor and acting head of the department of agricultural engineering in April, 1918. The following December he was made professor of agricultural engineering and became chairman of the department in January, 1920, holding the position ever since. In 1922 Iowa State College, Ames, Iowa, conferred the agricultural engineering degree upon Professor Sjogren.

In his earlier vacation periods as a student Professor Sjogren worked at the building trade, constructing masonry silos in various parts of the State and later conducted a pump irrigation investigation for the department of agricultural engineering of the University in cooperation with the United States Department of Agriculture. Professor Sjogren has been interested in tractors ever since they first came into use and was assistant to the tractor demonstration manager at the Fremont, Neb., demonstration in 1917. Prior to the demonstration he assisted in conducting an extensive series of tractor tests for the University of Nebraska. The following year he was engineer-in-charge of tests at the National Tractor Demonstration that was held at Salina, Kan. In March, 1919, Professor Sjogren was appointed a member of the tractor testing board of the University of Nebraska, under whose direction the well-known Nebraska Tractor Tests are conducted.

On Jan. 23, 1919, Professor Sjogren was elected to Member Grade in the Society. He has been a member of the Standards Committee since 1921, serving on the Tractor Division in that year and on the Agricultural Power Equipment Division that was formed to succeed it in 1922 to the present time. In 1924 and 1925 he was Vice-Chairman of this Division. The Tractor Rating Code that was adopted by the Society in June, 1925, was submitted by the Tractor Testing and Rating Subdivision of the Agricultural Power Equipment Division under the chairmanship of Professor Sjogren. In addition to membership in the Society he is also a member of the American Society of Agricultural Engineers, the Society for the Promotion of Engineering Education and several engineering and agricultural fraternities. Professor Sjogren has written a number of papers and bulletins on various subjects, several of the former, dealing with tractor testing, having been published in The Journal.

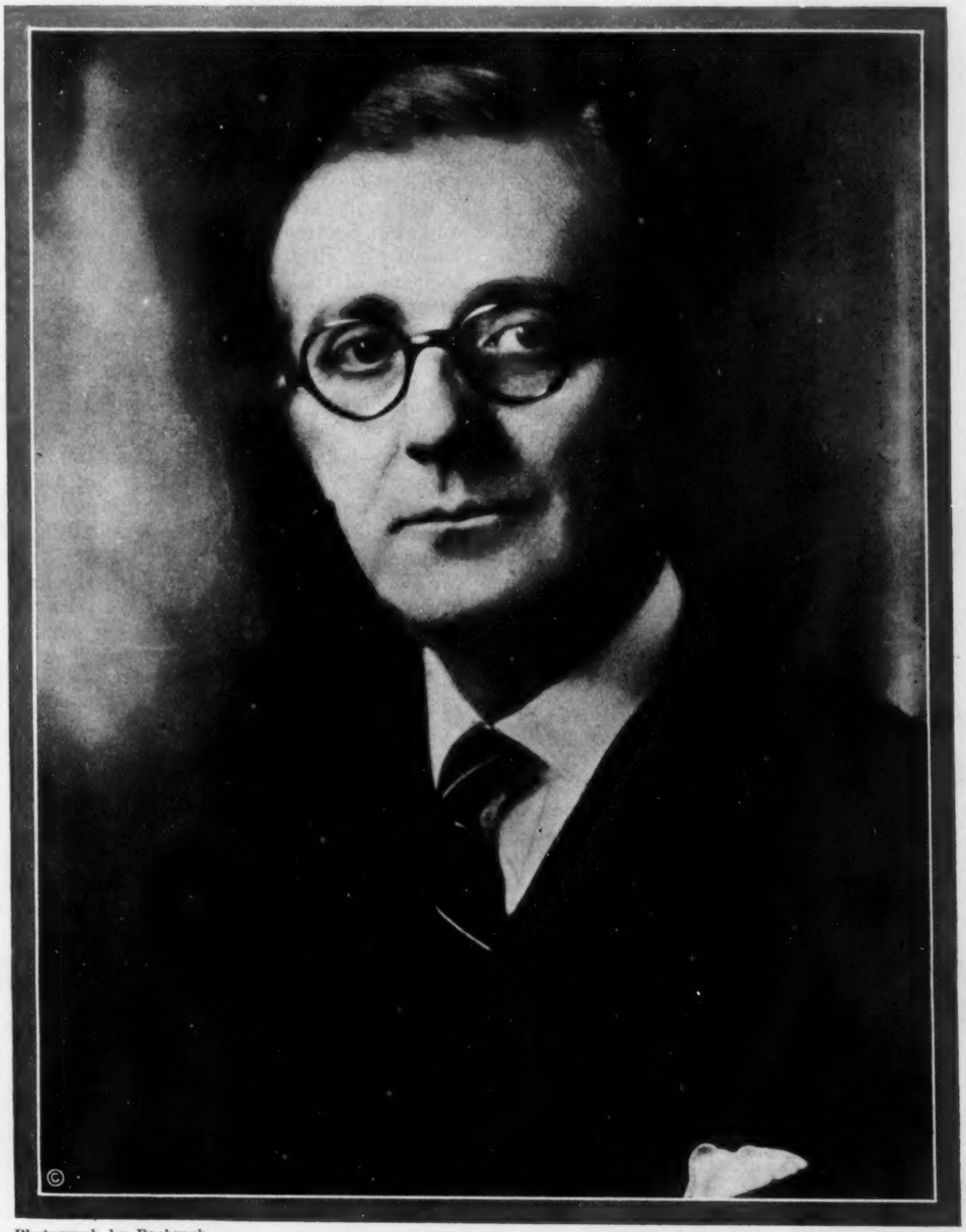
George F. Crouch

Second Vice-President Crouch representing marine engineering was born at Davenport, Iowa, in 1878. He received his technical education at the University of Wisconsin and Webb Institute of Naval Architecture and Marine Engineering, being graduated from the latter in 1901.

His connection with the motorboat industry dates back to its beginning in this Country as he has been associated ever since his graduation from Webb Institute with one branch or another. Mr. Crouch's first position was as a draftsman in the hull department of the William Cramp & Sons Ship & Engine Building Co., Philadelphia. Shortly afterward he was transferred to the electrical department where he was engaged in the laying out of the electrical equipment of the battleships that were then being constructed in the yards of the Company. Leaving the Cramp organization early in the spring of 1902, he came to New York City and entered the designing room of Tams, Lemoine & Crane where he was engaged in making calculations and drawings of yachts and commercial vessels. After 3 years of this work he was appointed assistant professor of mathematics at Webb Institute of Naval Architecture and Marine Engineering, New York City, holding this position until 1913 when he was made professor of naval architecture. While at Webb Institute Mr. Crouch maintained his interest in and his touch with the rapidly developing high-speed motorboats. From 1907 to 1920 he was technical editor of *Motorboat*, resigning in the latter year when his duties as head of the faculty of Webb Institute made it impossible for him to give the necessary time to any outside activities.

In 1923 he severed his connection with Webb Institute and for a little over a year was engaged in independent practice as a consulting engineer. In November, 1924, Mr. Crouch was elected vice-president of the Horace E. Dodge Boat Works, Inc., Detroit.

Two papers dealing with marine engineering subjects have been presented before the Society by Mr. Crouch.



Photograph by Bachrach

T. J. LÍTLE, JR.

The first of these entitled Automotive Applications of Marine Engines in the War was presented at the 1919 Annual Meeting of the Society and at the 1924 Motorboat Meeting he presented a paper on Engines for Motorboats. Mr. Crouch was elected to Member grade in the Society on March 22, 1919.

ARTHUR NUTT

Second Vice-President Nutt representing aeronautic engineering was born at New Rochelle, N. Y., on Feb. 6, 1895. When he was 4 years of age his family moved to Worcester, Mass., and his preliminary education was received in the grammar schools and the Classical High School of that city. In the fall of 1912, following his graduation from high school Mr. Nutt entered the Worcester Polytechnic Institute and was graduated from there in 1916 with the degree of bachelor of science in mechanical engineering. While at the Worcester Polytechnic he was a student member of the American Society of Mechanical Engineers and gained considerable experience in a practical way from his work in machine-shops and garages.

Following his graduation in June, 1916, Mr. Nutt went with the Curtiss Aeroplane & Motor Co., Inc., Buffalo, as a student. About 2 months later upon the abandonment of the course, which was to cover all phases of design in the construction of airplanes and engines, he obtained a position as test observer in the motor experimental department of that company. This gave him an opportunity to acquire a first-hand knowledge of all phases of engine development. From this position he was gradually advanced to test engineer and assistant engineer and in 1920 became chief engineer of the Motor Division of the Curtiss Company. In his positions as test and assistant engineer Mr. Nutt had to do with the development of many aircraft engines, the most important being the 400-hp. K-12 and the K-6 and C-6 six-cylinder water-cooled aircraft engines of from 150 to 160 hp. In his present position Mr. Nutt has had charge of the design and development of the D-12 and V-1400 engines. The former had the distinction of having won the Pulitzer Trophy races for 5 successive years and was outflown last year by the latter engine which won both Pulitzer and the Schneider Cup races. The Curtiss R-1454 400-hp. radial engine, which was designed and built in cooperation with the Air Service, was also under Mr. Nutt's supervision.

Mr. Nutt was elected to Member grade in the Society on March 7, 1922.

CHARLES O. GUERNSEY

Second Vice-President Guernsey representing stationary internal-combustion engineering was born at Vincennes, Ind., on Feb. 12, 1891. He received his technical education at the University of Illinois, being graduated in 1911 with the degree of mechanical engineer.

Upon leaving college Mr. Guernsey engaged in sales work with the Cole Motor Car Co. of Indianapolis, remaining there from March, 1912, until Dec. 1, 1913. At that time he accepted the position of factory manager and assistant chief engineer with the Service Motor Truck Co., Wabash, Ind., being promoted to chief engineer in June, 1915. In November, 1917, he was commissioned as Captain in the Motor Transport Corps and was stationed in the City of Washington where he had charge of the drafting and design of the Class AA, Class A, Class B and Militor trucks. Upon being discharged from the Government service in December, 1918, he resumed his position as chief engineer with the Service Motor Truck Co. and when that company was reorganized as the Service Motors, Inc., in January, 1922, he became chief engineer of that corporation. From March, 1922, to November, 1923, he was vice-president of the Service Motors, Inc. as well as manager of its rail-car division. On Nov. 1, 1923, he accepted the position of chief engineer of the automotive car division of the J. G. Brill Co., Philadelphia, a position that he still holds.

Mr. Guernsey was elected to Junior Member grade in the Society on Feb. 24, 1917 and was transferred to Member grade on June 25, 1917. He was elected Secretary of the Pennsylvania Section for the 1924 administrative year and was a member of the Meetings Committee of the Society last year. Papers presented by Mr. Guernsey include Cushioning in Motor-Truck Design and the Design of Motor Trucks for High-Speed Service which were presented in 1921 before the Mid-West and Indiana Sections respectively, Gasoline Driven Motor-Coach for Railroad Service which was presented at a meeting of the Indiana Section in 1922 and the Requirements of Gasoline Rail-Car Design which was presented at the 1925 Semi-Annual Meeting of the Society.

OTTO M. BURKHARDT

Councilor Burkhardt was born in Meissen, Germany, on Jan. 21, 1888. He received his elementary education in the schools of his birthplace and at the age of 17 entered the Technical Academy of Chemnitz, Germany, being graduated from there in 1907. The next year he worked as a designer in the Saechsische Maschinenfabrik Chemnitz, a plant that is noted for its fine locomotives. Mr. Burkhardt then entered the Technische Hochschule of Dresden, and was graduated in March, 1909, with the degree of engineer. After being graduated from Dresden he accepted a position as designer of electrical apparatus with the firm of Karl Flohr, of Berlin, but left shortly afterward to become a designer for Junkers & Co., remaining there until October, 1910, when he served for 1 year in the Engineering Corps of the German Army.

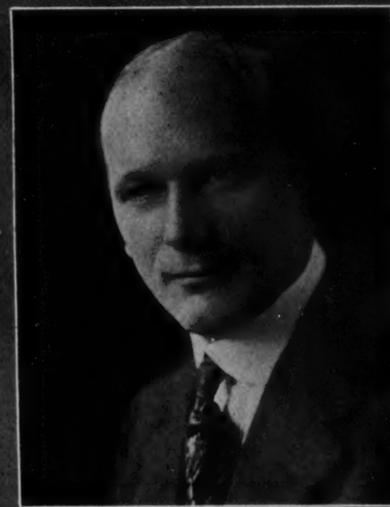
After leaving the army Mr. Burkhardt came to Toronto where he accepted a position as designer for the Russell Motor Car Co., which was then beginning to build Knight engines. In March, 1912, he accepted a position as designer with the Pierce-Arrow Motor Car Co., Buffalo, and was subsequently promoted to mathematical research engineer and in 1921 to consulting engineer. Early in 1925 Mr. Burkhardt resigned this position to become Research Manager of the Society.

Mr. Burkhardt was elected to Member Grade in the Society on Jan. 10, 1917. He has been prominent in the Buffalo Section of the Society, serving as its Treasurer, for the year beginning May, 1922. Two papers entitled Problems of Crankshaft Design and Progressive and Retrogressive Designing respectively have been presented by Mr. Burkhardt at meetings of that Section. Both of these have been published in THE JOURNAL, as has also his contribution entitled Valuation of Engine Performance. At the 1925 Annual Meeting of the Society he presented a paper entitled Wheel Shimmy—Its Causes and Cure, and one on Fundamentals of Brake Design at the Semi-Annual Meeting of that year. He served as a member of the Meetings Committee last year. Mr. Burkhardt was a member of the Lubricants Division of the Standards Committee in 1924.

FRANKLIN F. CHANDLER

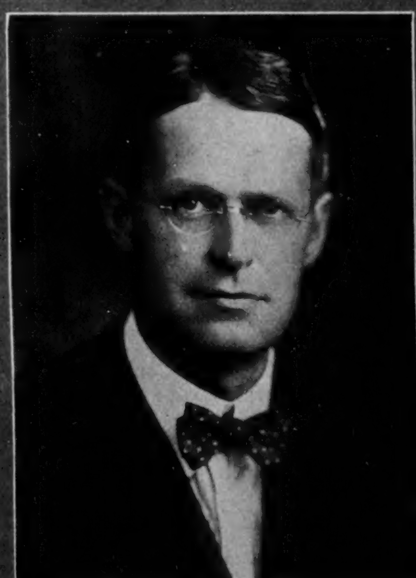
Councilor Chandler was born at Indianapolis on Dec. 27, 1876, and received his technical education at Purdue

G. F. CROUCH



G. W. SMITH

C. O. GUERNSEY



J. H. HUNT

ARTHUR NUTT

H. L. HORNING

O. W. SJOGREN

University, being graduated in 1899 with the degree of bachelor of science in mechanical engineering. After his graduation he taught machine design at that institution for 1 year.

The Chandler & Taylor Co., Indianapolis, was Mr. Chandler's first business connection. He became associated with this organization in May, 1900, and worked through several different departments, finally becoming manager of sales. While associated with the Chandler & Taylor Co. he was engaged in consulting engineering work and designed and installed complete powerplants as well as designing and building farm tractors. In April, 1923, Mr. Chandler went with the Ross Gear & Tool Co., Lafayette, Ind., as chief engineer, a position that he still holds. Since his association with the Ross Company, he has designed and built recording instruments for measuring the effort necessary to steer automobiles in motion.

In July, 1916, Mr. Chandler was elected a member of the board of trustees of Purdue University and at the present time, is chairman of the standing committee on technology and engineering, having held this appointment for several years.

Mr. Chandler was elected to Member grade in the Society on April 12, 1919. He has been prominent in the work of the Indiana Section, serving as Chairman for the administrative years 1923 and 1924 and as Vice-Chairman for the current year. At the April, 1924, meeting of the Indiana Section he presented a paper entitled Steering-Gear Analyses and was the author of a paper entitled How Hard Does a Car Steer which was presented at the 1925 Annual Meeting of the Society. Both of these papers described the instruments and work that he had done at the Ross Gear & Tool Co. Mr. Chandler was appointed a member of the Sections Committee in 1924 and served as its Vice-Chairman last year.

CLAUDE H. FOSTER

Councilor Foster was born on a farm at Brooklyn, Ohio, Dec. 23, 1873. He spent his early years in the usual pursuits of farm life and received his education in the elementary and high schools in the vicinity of his birthplace.

In the late 1890's he established a small machine-shop and bicycle business in Cleveland and gradually drifted into experimental work in the automobile field about 1898. This resulted in his becoming associated with the Winton Motor Car Co. in the early days of the industry.

After extensive experimenting and testing in 1903, Mr. Foster invented and patented a motor-car horn operated by the exhaust gas from the engine and having a musical or pleasing tone. The following year he organized the Gabriel Mfg. Co. to manufacture and market this horn and has been president of the company since its organization. He has invented and patented a number of shock-absorbing devices of various types which were marketed between 1906 and 1911 and in the following year invented and patented the Gabriel Snubber. His inventions include a special type of snubber to meet the requirements imposed upon such a device by balloon and low-air-pressure tires.

Mr. Foster was elected to Member Grade in the Society on Feb. 6, 1911.

TALIAFERRO MILTON

Councilor Milton was born at Berryville, Va., on March 26, 1877. He received his education in the public and high schools of his birthplace and also at the Virginia Military Institute, Lexington, Va., receiving the degree of bachelor of science in 1900. He was commandant of the Sewanee, Tenn., Grammar School for the year 1897-1898, leaving to accept the position of assistant professor of mathematics at the Virginia Military Institute, where he remained until 1903, being assistant professor of physics for 4 years.

In 1903, Mr. Milton took the apprentice course at the Westinghouse Electric & Mfg. Co., East Pittsburgh, Pa., and in 1905 entered the service of the New York Central & Hudson River Railroad in its engineering department where he was connected with the work on the New York City electrified zone. He accepted a position as sales engineer in the Chicago office of the Gould Storage Battery Co. in 1906 and the following year became associated with the Electric Storage Battery Co. as sales engineer in its Cleveland office. For the next 2 years he was attached to the San Francisco office of that company in the same capacity. In 1909 he was promoted to district engineer with headquarters at Chicago and has been manager of the Chicago branch of the Electric Storage Battery Co. since 1920.

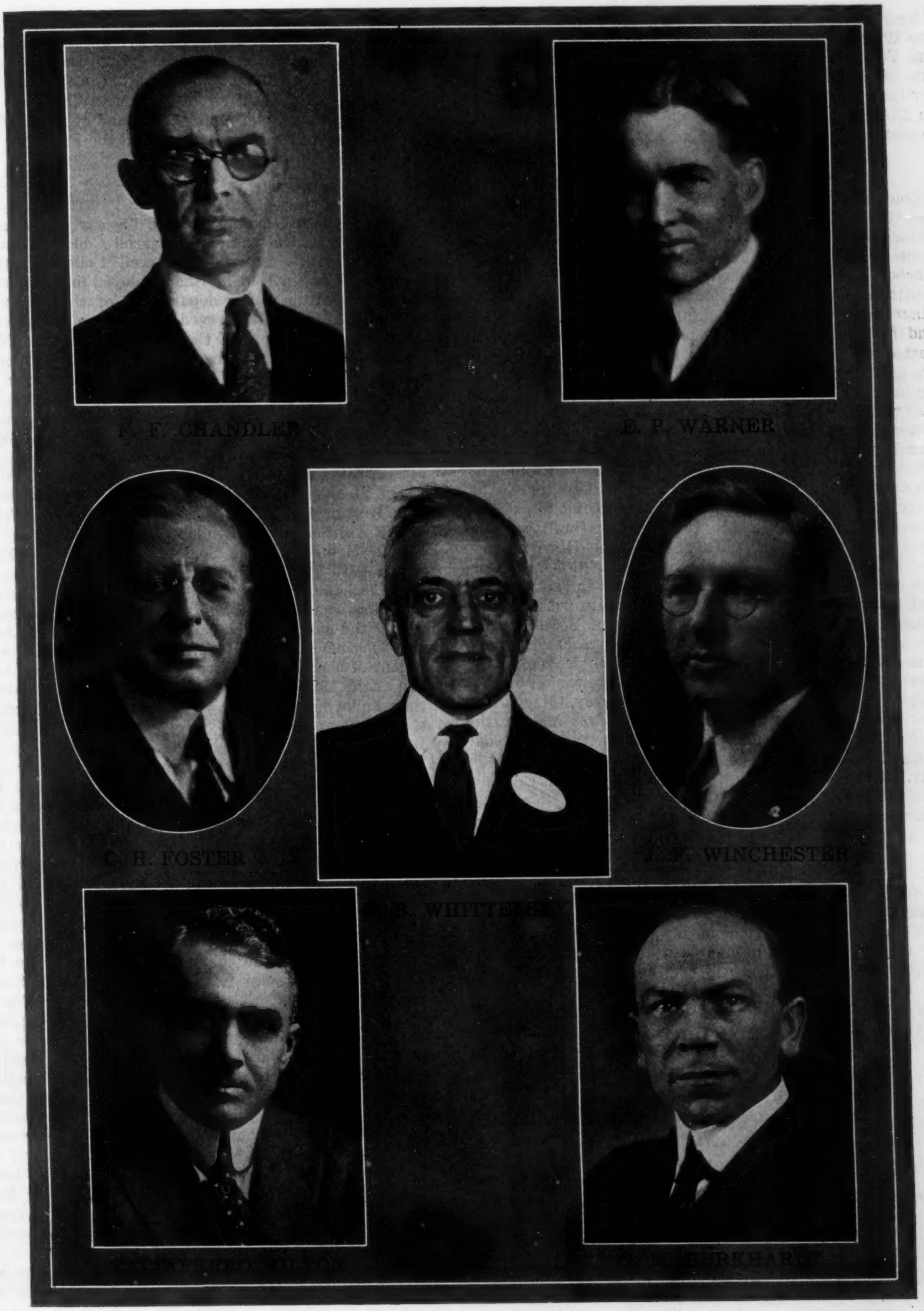
Mr. Milton was elected to Member grade in the Society on June 23, 1913. He is also a fellow of the American Institute of Electrical Engineers and a member of the Western Society of Engineers. In 1921 he was elected Secretary of the Mid-West (now the Chicago) Section of the Society and served as Chairman of the Section the following year and as Vice-Chairman for the year 1923. He was a member of the 1924 Meetings Committee of the Society. Mr. Milton was a member of the executive committee of the Chicago Section of the American Institute of Electrical Engineers for several years, serving as Secretary of the Section for the Administrative year 1915-1916 and as Chairman of the Section the following year.

E. P. WARNER

Councilor Warner was born in Pittsburgh on Nov. 9, 1894. He was educated at the Volkman School, Boston, and after being graduated from Harvard University with the degree of bachelor of arts in 1916, attended the Massachusetts Institute of Technology, receiving the degree of bachelor of science in 1917 and that of master of science in 1919.

During the war he was employed as aeronautical engineer for the Air Service in connection with research and also as instructor in the military course in aeronautical engineering at the Massachusetts Institute of Technology. From January, 1919, to June, 1920, he served the National Advisory Committee for Aeronautics as chief physicist, directing aeronautical research work at Langley Field; and for 3 months after that time he continued with the Committee as acting technical assistant in Europe. Since the fall of 1920 he has been a member of the faculty at the Massachusetts Institute of Technology where he is now professor of aeronautic engineering.

Professor Warner was elected to Member Grade in the Society in 1917. He is also a member of the American Society of Mechanical Engineers, the Society of Naval Architects and Marine Engineers, the American Physical Society and an associate fellow of the Royal Aeronautical Society. He is the author of about 80 published reports and papers, including one on Commercial Aviation in the Eastern Hemisphere which was presented at the Annual Meeting in 1921; Airplane Performance Formulas, at the 1922 Semi-Annual Meeting; Design of Commercial Airplanes, at the 1923 Annual Meeting, and Commercial Aviation, at the November, 1923, meeting of the Metropolitan Section. Professor Warner was elected Second



F. F. CHANDLER

E. P. WARNER

C. H. FOSTER

B. WHITTELSEY

J. F. WINCHESTER

BURKHART

Vice-President representing aeronautic engineering at the 1923 Annual Meeting and has served as Chairman of the Publication Committee for the last 3 years. He is one of the Vice-Chairmen of the New England Section for the current year, as well as representing that Section on the Sections Committee, and was a member of the Research Committee for 1925.

J. F. Winchester

Councilor Winchester was born at Walpole, Mass., on Dec. 13, 1885, and received his education in the public schools of New England. He learned the machinist trade at the Vaughan Machine Co., Peabody, Mass., and subsequently was employed by the Upton Machine, Waltham Automobile and Machine Sales Companies and other organizations as machinist, tool maker, inspector and foreman on the earliest models of automobiles, imported and experimented with in this Country. During this period Mr. Winchester studied mechanical engineering and similar subjects allied with the automobile industry in the evening schools of New England and at the Boston Young Men's Christian Association as well as pursuing correspondence courses.

With this experience and training as a background he was employed in May, 1910, by the Hewitt Motor Co. as factory and service inspector, his duties being to pass on the construction of all 5 to 10-ton trucks built by this organization. In April, 1913, he left the Hewitt Company to enter the service of the Standard Oil Co. of New Jersey as sales engineer, specializing in automobile lubricating and sales work. When the growth of the Company's automotive equipment made it necessary to have some one person responsible for its mechanical condition Mr. Winchester was made automotive engineer and equipment manager and given the supervision of the Company's sales equipment in New Jersey, Maryland, District of Columbia, Virginia, West Virginia and North and South Carolina. This is the position that he holds at the present time.

Mr. Winchester was elected to Member grade in the Society on June 23, 1919. He has taken an active part in public and semi-public affairs relating to transportation and was one of the organizers of the Motor Truck Club of New Jersey, serving as its secretary for several years and then as its president. For a number of years Mr. Winchester has contributed articles on subjects pertaining to the automobile industry and allied topics to trade and technical periodicals as well as newspapers. Over a period of years he has been active in the Society and at the April, 1924, meeting of the Metropolitan Section, he presented a paper entitled Observations of a Superintendent of Motor-Truck Fleet-Operation. This was based upon his own experience with the Standard Oil Co.

Charles B. Whittelsey

Treasurer Whittelsey was born at New Haven, Conn., on March 16, 1869. His education has been gained chiefly through practical contact with business.

His connection with the automotive industry dates from 1901, when he became associated with the Hartford Rubber Works Co. In 1911 Mr. Whittelsey became factory manager of the organization, and in 1916 he was elected to the presidency, which office he has held ever since.

Mr. Whittelsey was elected to the Member grade of the Society in 1910, and to Life Member grade in 1916. He was appointed on the Standards Committee in 1911 and served for several years, being Chairman of the Tire and Rim Division in 1918 and 1919. Mr. Whittelsey was a member of the Council in 1912 and 1913. In 1918 he was elected Treasurer of the Society, which office he has held continuously since that time. At present he is also a member of the Finance and Resignations Committees.

At the Annual Meeting in 1912 Mr. Whittelsey presented a paper on Solid Motor Tires and at the 1915 Annual Meeting he read a paper entitled the Pros and Cons of Tire Inflation.

H. L. Horning

Past President Horning secured his early training in the modern classical course at Carroll College Academy and the scientific course at Carroll College, both at Waukesha, Wis. In 1901 he was employed in the chemical laboratory and operating department of the Milwaukee Gas Light Co. and later served for 2 years in the steam engineering department of the Crane Co. From 1904 to 1906 he was head of the mechanical engineering department of the Modern Steel Structural Co., his most important work at that time being the construction and mechanical operation of the Duluth steel bridge, one of three structures of the kind in the world. In 1906 he established the Waukesha Motor Co.

Mr. Horning has been a member of the American Society of Mechanical Engineers, and of the Association for the Advancement of Science, and was elected a Fellow of the Royal Society of London early in 1925. He was elected a Member of the Society of Automobile Engineers in 1910 and through his connection with the Society of Tractor Engineers and the National Gas Engine Association was active in the movement that resulted in changing the name of the Society to the Society of Automotive Engineers. Mr. Horning was elected third vice-president of the Motor & Accessory Manufacturers Association at the 1924 annual meeting and first vice-president at the annual meeting last year. He is also a member of the Street and Highway Safety Committee organized by Secretary of Commerce Hoover.

He was chairman of the automotive products section of the War Industries Board, Council of National Defense, during the war. He served as chairman of the Design Committee of Engineers that laid out the engines for the Class B and Class AA military trucks. He was the first chairman of the Tractor Division of the Standards Committee and was a member of the first Oil and Fuel Committee established by the Council of the Society.

Truck and Tractor Engines was the subject of a paper he presented in 1916 at a Mid-West Section meeting. At the 1917 Annual Meeting he presented a paper on the Ultimate Type of Tractor Engine and at the 1917 Semi-Annual Meeting he gave a paper on the Farm Tractor as Related to the Food Problem. He also presented a paper on Tractor Engines and Fuel Limitations before the Detroit Section in 1919, at the 1921 Semi-Annual Meeting read his paper on Turbulence, and in 1923 at a meeting of the Mid-West Section he analyzed the Effect of Compression on Detonation and Detonation Control. In the last year Mr. Horning has addressed a number of the Sections, his topics being Road and Riding Ability, at the Cleveland Section; Recent Progress in Various Fields of Automotive Engineering, at the Chicago Section; Engine Lubrication, at the Tractor Meeting; and Lubrication, at the initial meeting of the Southern California Section.

As a representative of the Society, Mr. Horning accompanied the National Screw Thread Commission on

(*Concluded on p.* 162)

Progress Report on Engine-Starting Tests

By JOHN O. EISINGER[1]

ANNUAL MEETING PAPER *Illustrated with* CHARTS

ABSTRACT

THIS report supplements previous progress reports on the Cooperative Fuel Research and brings uptodate the information on engine-starting tests that were made in the last year. Tests made with two types of standard carbureter show that the laboratory test-apparatus gave similar results as regards time required for starting the engine and that throttling with the test set-up produced similar results as throttling with one of the carbureters. For subsequent starting-tests with the test set-up, the former cranking speed was reduced from 200 to 100 r.p.m.

Tests were made at different air-temperatures with three fuels having different distillation-characteristics as designated by the Steering Committee, which had stressed the importance of obtaining information as to the magnitude and nature of the changes in fuel that would be necessary to make starting as easy in cold weather as in warm. Comparisons between two fuels having rather widely different distillation-characteristics were made at air-inlet temperatures of 68 and 36 deg. fahr. and indicate wide differences in starting time at the lower temperature. As different amounts of the two fuels are required to start the engine in a given time, it is indicated that different amounts are vaporized, which is supported by the distillation curves that show proportionately wider differences in distillation as the temperature is reduced.

Starting performances of another pair of fuels were closely similar at an air temperature of 81 deg. fahr. but at 25 deg. fahr. one failed to start the engine while the other started it in from 10 to 29 sec. at different rates of fuel-flow. A third pair of fuels that had the same distillation-characteristics up to 10 per cent of the fuel, gave approximately the same starting performance at 43 deg. fahr., hence it seems probable that less than 10 per cent is vaporized under these conditions, but at an air temperature of 68 deg. fahr. differences in starting performance which indicate that considerably more than 10 per cent is vaporized are found.

Comparison of a fourth pair of fuels, one of which was a 50-per cent benzol blend, shows that the latter gives quicker starting than the other at a lower rate of fuel flow at an air temperature of 66 deg. fahr., whereas at 30 deg. the benzol blend requires a longer starting time with a high rate of flow and less time with a low rate of flow. Thus, the same amount of the two fuels is needed to start the engine in 7 sec., but more benzol blend is needed to start it in 4 sec. and less to start it in 10 sec.

The tests indicate that within certain limits richness of the fuel determines the number of revolutions the engine must make before an explosion is obtained. Richness of the mixture in the cylinder rather than that of the mixture leaving the carbureter determines whether or not an explosion will occur, and this is believed to be a function of delayed vaporization of fuel left in liquid form in the manifold and cylinder during previous cycles.

If the fuel characteristics could be changed gradually as cold weather approaches, somewhat as the distillation curves and the starting performances of the different fuels at various temperatures indicate to be desirable, it might be possible to obtain very nearly the same starting performance in winter as in summer. One of the purposes of the research is to determine the general nature and magnitude of the changes that might accomplish this result.

DURING the last year the Cooperative Fuel Research[2] has consisted for the most part of a study of engine starting. At the Semi-Annual Meeting of the Society last June a report was presented which described the general method that had been developed for this purpose and the results that had been obtained at that time. The engine used for these tests is a four-cylinder truck engine having a bore of 4¾ in. and a stroke of 6 in. For these experiments the carbureter is replaced by a single jet mounted in a vertical section of pipe. This pipe, which is about 10 in. long, is connected to and has the same inside diameter as the intake-manifold. Flanges are provided at both ends of this vertical pipe. Ordinarily, a flat-plate orifice mounted upon the upper flange served as a throttle and, when

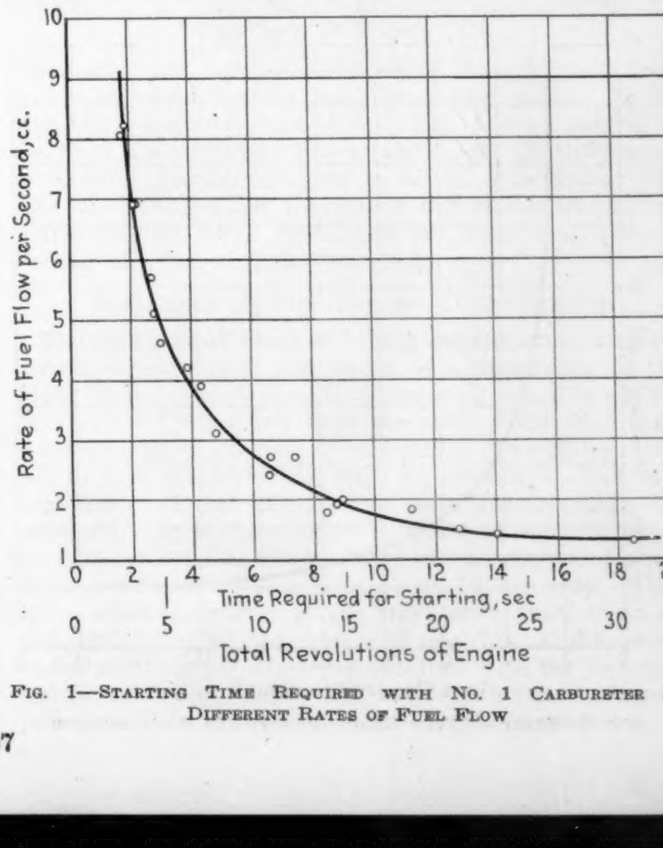


FIG. 1—STARTING TIME REQUIRED WITH NO. 1 CARBURETER AT DIFFERENT RATES OF FUEL FLOW

[1] Jun. S.A.E.—Automobile powerplant section, Bureau of Standards, City of Washington.

[2] This Cooperative Fuel Research has been in progress at the Bureau of Standards since August, 1922, under direction of a Steering Committee composed of representatives of the cooperating organizations, which are the American Petroleum Institute, the National Automobile Chamber of Commerce, the Bureau of Standards, and the Society. For reports of previous work see THE JOURNAL, February, 1923, p. 139; July, 1923, p. 3; March, 1924, p. 268; July, 1924, p. 69; October, 1924, p. 334; February, 1925, p. 237; and July, 1925, p. 52.

occasion required, an orifice was also mounted upon the lower flange to serve as a choke.

The test procedure was as follows: The engine was driven by a dynamometer at a constant speed and with the fuel supply shut off. When engine conditions had become reasonably constant, fuel was turned on and the time required to obtain an audible explosion was taken by a stop-watch. This was regarded as the starting time. Then the fuel was shut off immediately, and from the reading of a burette, which was used to measure the fuel delivered to the jet, the total amount of fuel used in starting the engine was determined. The starting time and the amount of fuel used were obtained for different rates of fuel-flow from the jet. In presenting the results, these different rates of fuel-flow, which correspond to different mixture-ratios, since the engine speed was constant, were compared with the time required for starting.

Among the factors, the influences of which were discussed in the above-mentioned report, were fuel-air ratio, jet size, jet location, spark-advance, fuel volatility, amount of throttling, amount of choking, temperature of jacket-water, and temperature of entering air.

Test Apparatus Gave Starting Results Similar to Standard Carbureters

Before proceeding with further work on this subject, it seemed desirable to make certain that the apparatus used in these tests did give performance, as regards starting, similar to that which would be obtained with standard motor-car equipment, particularly as regards the means of supplying the fuel for starting. The apparatus, as originally designed, was intended to reproduce the essential features of all carbureters and the special features of none. Several tests were made with two types of carbureters that are in common use to determine whether the original apparatus did give results of the same general character as would be obtained with conventional carbureters.

Figs. 1 and 2 show typical results obtained with the two carbureters and Fig. 3 shows those obtained with the test apparatus. It will be noted that the curves in these three figures are similar in character, although the actual amounts of fuel required for starting in a given time are, of course, different, due to differences in jet location and other factors. The test apparatus appears, therefore, to reproduce satisfactorily the conditions that prevail in the ordinary carbureter. Fig. 4, which shows results at various throttle-openings when using carbureter No. 1, further supports this conclusion, since throttling had been shown to produce similar results with the test set-up.

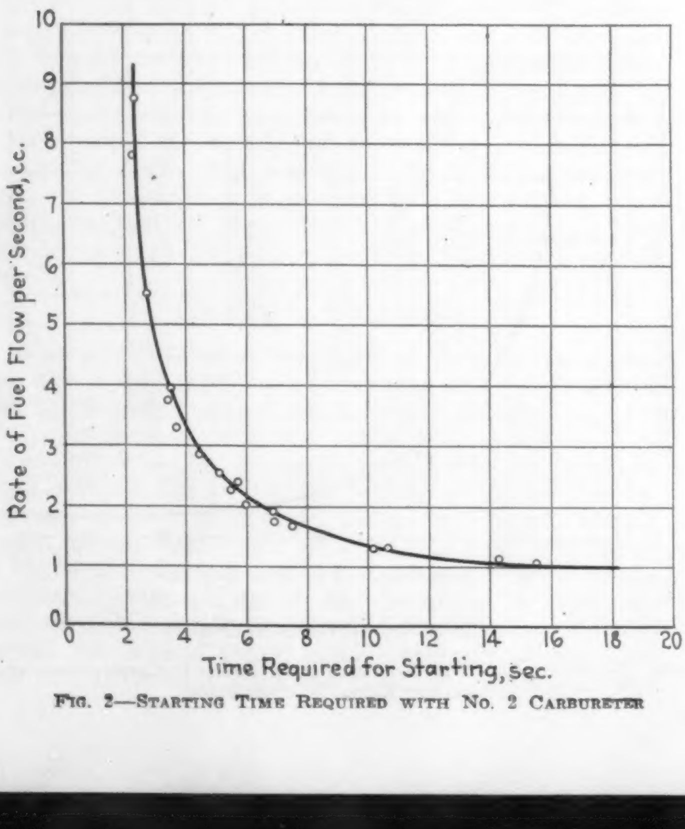


Fig. 2—Starting Time Required with No. 2 Carbureter

Subsequent experiments were therefore made with essentially the same apparatus as was used originally. Instead of employing a cranking speed of 200 r.p.m., however, a speed of 100 r.p.m. was adopted as corresponding more closely with actual service conditions. Erratic results were obtained at this speed at first but eventually the various sources of inconsistency, the chief of which proved to be faulty ignition, were found and eliminated.

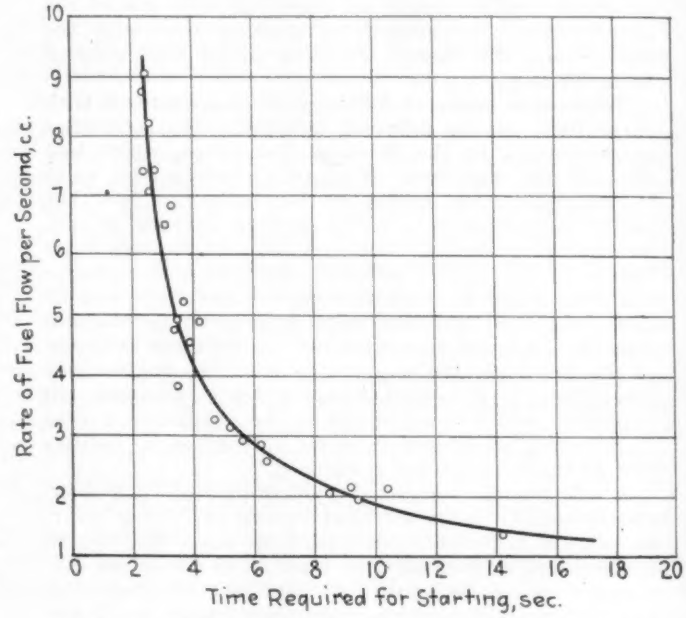


Fig. 3—Starting Time Required with Test Set-Up

Tests of Fuels at Various Temperatures

The starting problem and starting difficulties become emphasized, ordinarily, upon the advent of cold weather. For this reason the Steering Committee had stressed the importance of obtaining information as to the magnitude and nature of the changes in fuels which would be necessary to compensate for changes in atmospheric temperature. As a step in this direction, the Committee recommended that tests be made of the three fuels whose distillation characteristics are shown in Fig. 5. A comparison of fuels Nos. 2 and 3 at an air temperature of 20 deg. cent. (68 deg. fahr.) and a similar comparison at a temperature of 2 deg. cent. (36 deg. fahr.) are shown in Fig. 6.

In making starting-tests, it would be very desirable, in discussing the probable starting characteristics of fuels, to have some method of measuring their effective volatility. The distillation curve does not furnish all that would be desired in this respect, because the conditions of the distillation test do not approximate the conditions of vaporization in the manifold. In this paper, therefore, when distillation data are referred to, no implication is made that a definite relationship between the distillation curve and the starting properties of a fuel

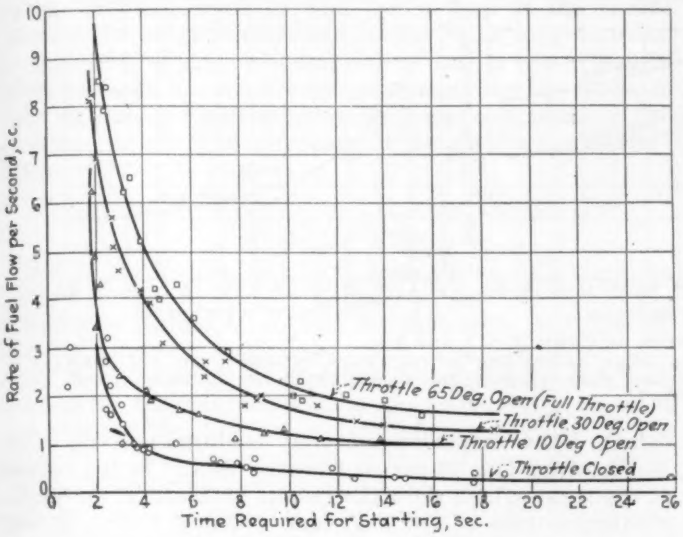


FIG. 4—STARTING RESULTS AT VARIOUS THROTTLE OPENINGS WITH CARBURETER NO. 1

These Support the Evidence of Figs. 1, 2 and 3 That the Test Set-Up Duplicates Standard Motor-Car Equipment So Far as Starting Is Concerned, Since Throttling Has Been Shown To Produce Similar Results with the Test Set-Up

exists, yet the use of the one affords a better understanding of the other.

FUELS VARY IN AMOUNT VAPORIZED

Fuels Nos. 2 and 3 showed differences in starting characteristics at both temperatures, the differences being greater at the lower temperature. The minimum amount of fuel vapor necessary to form a combustible mixture with air is essentially the same for all gasolines. It follows then that no difference in the starting performance of these fuels would be found if the temperatures were sufficiently high so that practically all of the fuel was vaporized in the air-fuel mixture. The temperature of complete vaporization in an air-fuel mixture is far below the temperature of the end-point of the distillation curve and is probably, for the fuels here considered, below 70 deg. cent. (158 deg. fahr.). The fact that different quantities of the two fuels are required to produce starting in a given time indicates, therefore, that at the temperature of operation, different quantities of the two fuels are vaporized. This is suggested by the distillation curves in Fig. 5, which show that differences between the two fuels exist below the 85-per cent point, which differences become proportionately greater as the temperature is decreased. It would, therefore, be expected that differences in starting performance of these two fuels would become more pronounced as the temperature of operation is lowered.

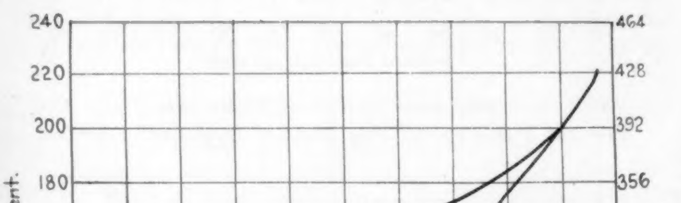


FIG. 5—DISTILLATION CURVES OF THREE FUELS RECOMMENDED FOR TESTS BY THE STEERING COMMITTEE OF THE COOPERATIVE FUEL RESEARCH

Below the 85-Per Cent Point a Marked Difference Is Noted between Fuels Nos. 1 and 3 and Fuel No. 2, Which Difference Becomes Proportionately Greater as the Temperature Is Reduced

Fig. 7 shows starting characteristics of fuels Nos. 1 and 3. As shown by the curves at the left, these two fuels gave similar starting performance at an air temperature of 27 deg. cent. (81 deg. fahr.). However, if the temperature of the intake air is lowered to 2 deg. cent. (36 deg. fahr.), the jacket-water remaining at a somewhat higher temperature, a marked difference is noticed in the performance of these two fuels, as shown in central pair of curves. When the jacket-water and air temperatures are further lowered, as shown at the right, starting could not be obtained with fuel No. 1. The general results would likewise be expected from an examination of

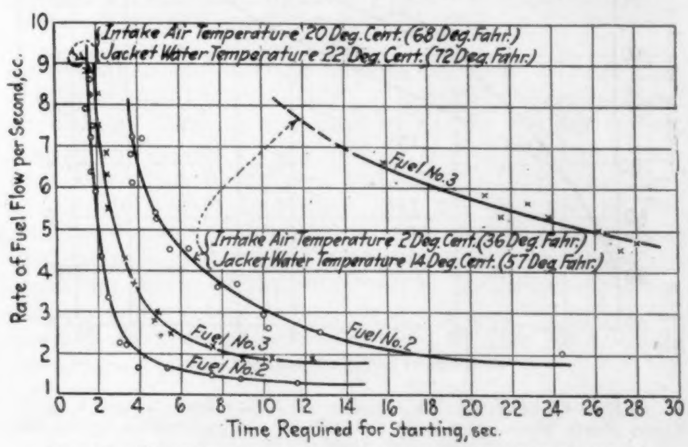


FIG. 6—STARTING CHARACTERISTICS OF FUELS NOS. 2 AND 3

Performance of the Two Fuels Is Fairly Similar at an Intake-Air Temperature of 68 Deg. Fahr., but Widely Different at an Air Temperature of 36 Deg. Fahr.

the distillation curves, which show that the two fuels are in agreement above the 25-per cent point. If the temperature of operation is such that a large portion of the fuels are vaporized, one would expect the differences in starting characteristics to be small. For similar reasons one would expect appreciable differences in starting characteristics when conditions are such that a small portion of either fuel is vaporized.

INFLUENCE OF LOW-BOILING CONSTITUENTS

The influence of the low-boiling constituents on starting characteristics is also shown by a comparison of two fuels, Nos. 3 and 6, the distillations of which are given in Fig. 8. These fuels have the same distillation characteristics up to the 10-per cent point. The curve at the left of Fig. 9 shows that, with an air temperature of 6 deg. cent. (43 deg. fahr.), they gave approximately the same starting performance. It seems reasonable, therefore, to believe that the quantity of fuel vaporized under these conditions is less than about 10 per cent. Similarly, since the curves at the right show that, at an air temperature of 20 deg. cent. (68 deg. fahr.), differences in the starting performances obtained with the two fuels are found, it is probable that considerably more than 10 per cent of the fuel is vaporized at this temperature.

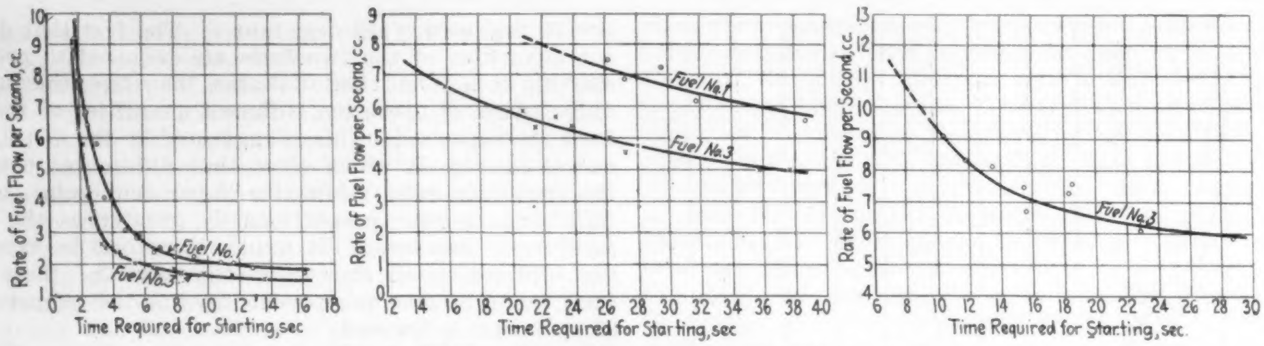


FIG. 7—STARTING CHARACTERISTICS OF FUELS NOS. 1 AND 3

Differences Are Shown Both at an Air Temperature of 81 Deg. Fahr. (Left) and 36 Deg. Fahr. (Center), but Are Much Greater at the Lower Temperature. At a Temperature of 25 Deg. Fahr. (Right), the Engine Could Not Be Started with Fuel No. 1

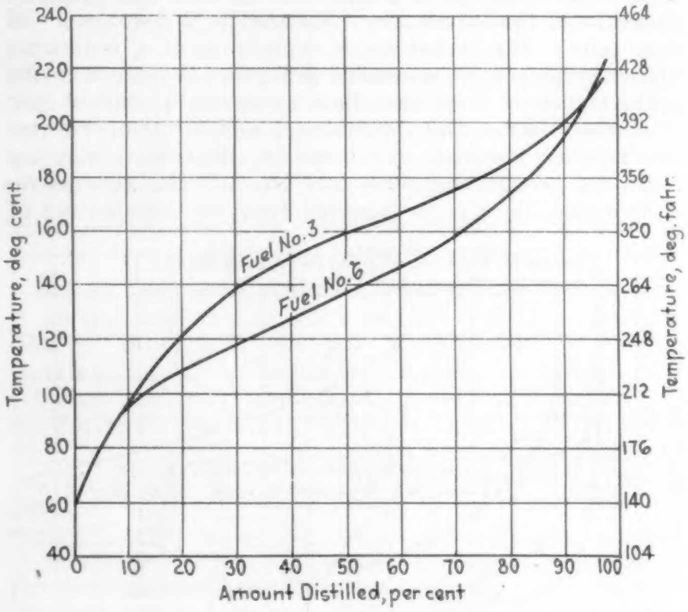


FIG. 8—DISTILLATION CURVES OF FUELS NOS. 3 AND 6

These Fuels Have the Same Distillation Characteristics up to the 10-Per Cent Point

Possibly the most interesting comparisons to date are those that have been made with the two fuels, Nos. 6 and 7, whose distillation characteristics are shown in Fig. 10. The curves at the left of Fig. 11, which give the results obtained at an air temperature of 19 deg. cent. (66 deg. fahr.), show superior starting performance for fuel No. 7, which is a 50-per cent benzol blend. In the curves at the right, which show the results obtained at an intake air-temperature of —1 deg. cent. (30 deg. fahr.), it will be noted that the curves of fuel-flow versus starting time

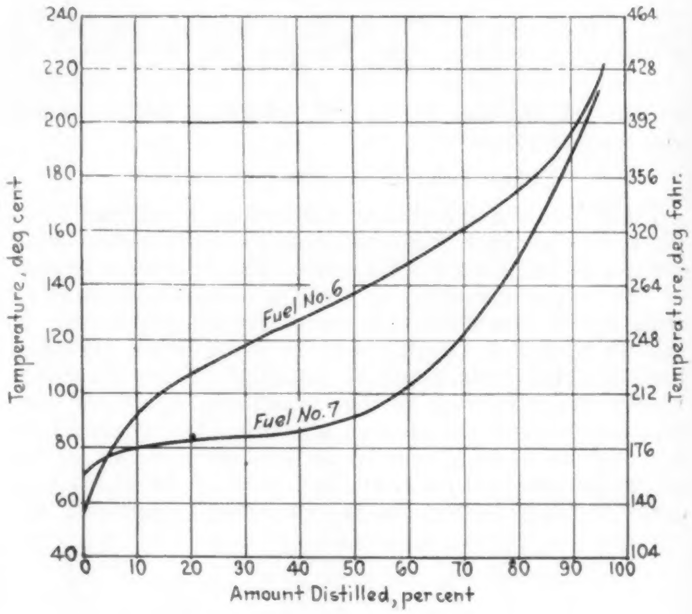


FIG. 10—DISTILLATION CURVES OF FUELS NOS. 6 AND 7

Fuel No. 7 Is a 50-Per Cent Blend of Benzol and Gasoline

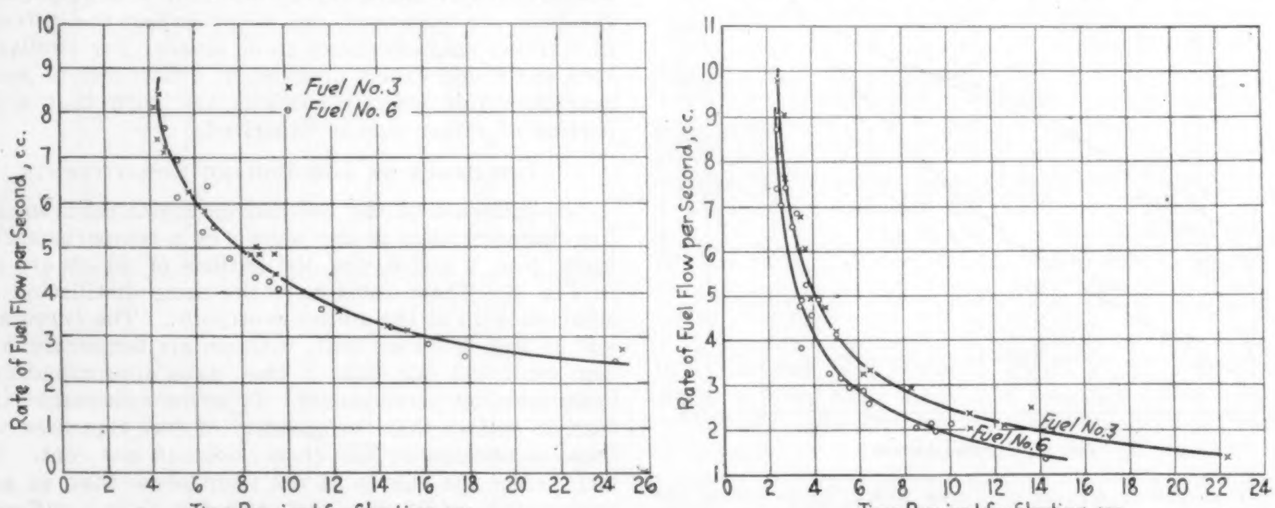


FIG. 9—STARTING CHARACTERISTICS OF FUELS NOS. 3 AND 6

The Curves at the Left Show That, with an Air Temperature of 43 Deg. Fahr., the Two Fuels Gave Approximately the Same Performance, Indicating That Less than 10 Per Cent of the Fuel Was Vaporized. Curves at the Right Show Starting Differences, with an Air Temperature of 68 Deg. Fahr., Which Indicate That More than 10 Per Cent Was Vaporized

cross, and that more of fuel No. 6 than of the benzol blend is required to start the engine in 12 sec., whereas, if the starting time is 6 sec., the reverse is true. Before attempting to discuss the comparison of the two fuels, it may be well to recall some of the comments made in the previous report with reference to the starting characteristics of fuels in general.

Richness of Mixture in Cylinder Determines Starting Time

All of the curves that have been shown indicate that, within certain limits, the richness of the mixture determines the number of revolutions that must be made before an explosion is obtained. The "richness of the mixture" here referred to, however, is based upon the fuel-content of the mixture leaving the carbureter, which is not necessarily the fuel-content of the mixture in the cylinder. It is the mixture in the cylinder that determines whether or not an explosion will occur, and the figures must be considered as showing the relation of the fuel-air ratio leaving the carbureter to the time required for the mixture in the cylinder to become rich enough to fire. Presumably the increase in richness of the mixture in the cylinder is primarily the result of delayed vaporization. The mechanism of this delayed vaporization is believed to be as follows:

In successive cycles an increasing portion of the fuel reaches the engine cylinder and becomes vaporized by the time of ignition. This is due to the fact that to the fuel supplied by the carbureter is added a certain amount of fuel vapor resulting from vaporization of fuel which in previous cycles had been left in liquid form in the manifold and cylinders. The extent of this vaporization of liquid fuel in the manifold depends more or less upon the time allowed for the vaporization, that is, upon the time required for starting.

Since the curves at the right of Fig. 11 show that less of No. 7 than of fuel No. 6 is required when the starting time is long, it would follow that a greater quantity of fuel No. 7 is vaporized under such conditions. From an examination of the distillation curves of these fuels, one would expect a condition at any temperature such that more than from 5 to 20 per cent vaporizes. Inasmuch as less of fuel No. 6 than of fuel No. 7 is required when the starting time is short, it appears that a greater quantity of fuel No. 6 is vaporized under these conditions. And, as indicated by the distillation curves, one would expect a condition at any temperature such that less than 5 per cent vaporizes. From the foregoing analyses it is evident that the quantity of fuel vaporized under these temperatures of operation is about the same for both fuels, being more or less dependent upon the length of time required to obtain an explosion. At somewhat lower temperature the total quantity vaporized would be decreased and less of fuel No. 6 would be required under all conditions.

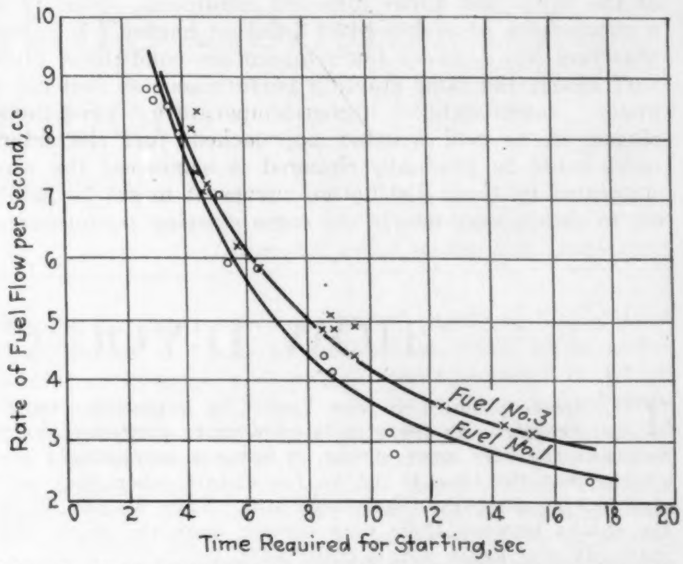


Fig. 12—Close Correspondence of Starting Characteristics of Fuels Nos. 1 and 3 at Different Air-Temperatures

This Similarity of Performance of Fuel No. 1 at an Air Temperature of 68 Deg. Fahr. and Fuel No. 3 at 43 Deg. Fahr. Suggests That, if Fuel Characteristics Could Be Changed Gradually as Cold Weather Approaches, It Might Be Possible To Obtain Nearly the Same Engine-Starting Performance in Winter as in Summer

Fuel Characteristics Might Be Changed To Suit Temperature Conditions

Thus far the curves have shown comparisons of different fuels under the same temperature conditions, or

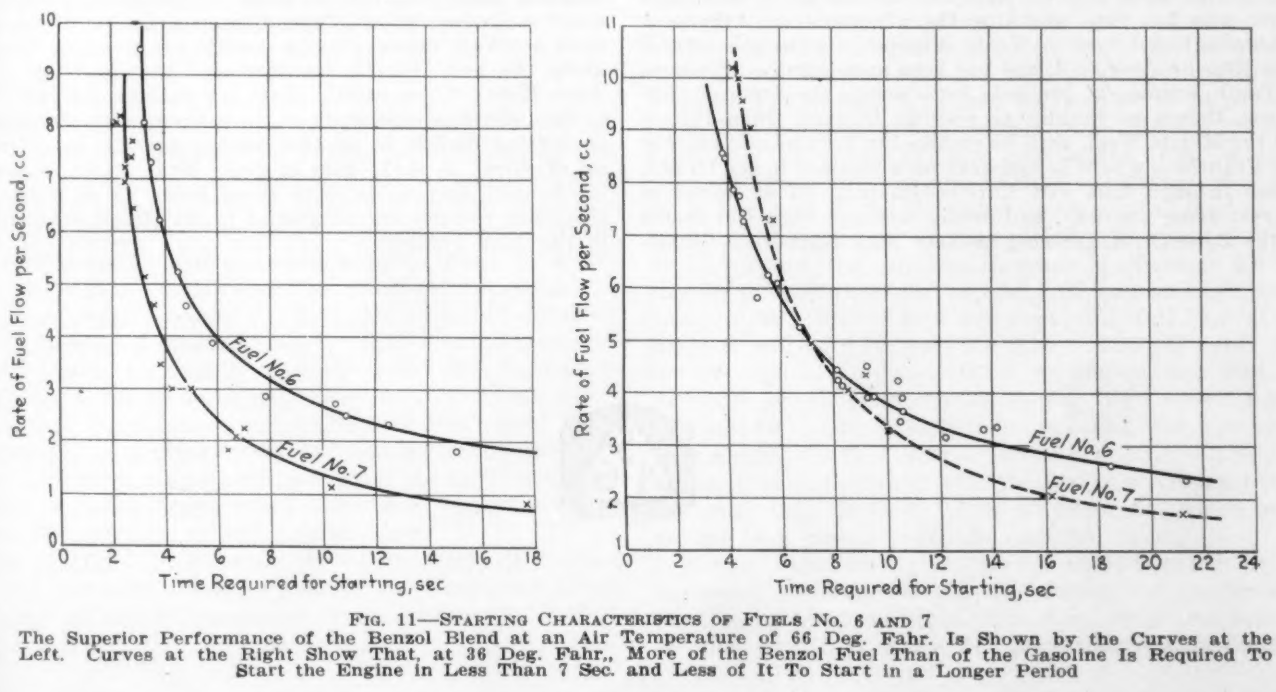


Fig. 11—Starting Characteristics of Fuels No. 6 and 7

The Superior Performance of the Benzol Blend at an Air Temperature of 66 Deg. Fahr. Is Shown by the Curves at the Left. Curves at the Right Show That, at 36 Deg. Fahr., More of the Benzol Fuel Than of the Gasoline Is Required To Start the Engine in Less Than 7 Sec. and Less of It To Start in a Longer Period

of the same fuel under different conditions. Fig. 12 is a comparison of a somewhat different nature. It shows that fuel No. 3, under low-temperature conditions, gives very nearly the same starting performance as fuel No. 1 under considerably higher-temperature conditions. Hence, if, as cold weather approached, fuel characteristics could be gradually changed in somewhat the way suggested by these distillation curves, it might be possible to obtain very nearly the same starting performance in winter as in summer. It is not implied that these two fuels represent ideal winter and summer fuels or even that it is feasible to change fuel characteristics to such an extent as wholly to compensate for temperature changes. Nevertheless, it cannot be denied that such changes would be highly desirable from the standpoint of engine operation, and one of the purposes of this research is to determine the general nature and magnitude of the changes that might accomplish this result.

HOW D'YOU GET WHAT WAY?

THE traffic problem in New York City is getting simpler and simpler. As the streets grow more congested every day, and the cars move slower, it becomes increasingly apparent that the time is not so far distant when they will stop moving altogether and stand still. Then we can fill in the chinks between them with cement, pave the hoods and start life over again with a clean slate.

The credit for this easy solution to what appeared for a time to be a serious problem can be traced to a number of sources, all of which are members of the Traffic Commission. As a result of an exhaustive investigation of street conditions in New York City the last 25 years, this Commission rendered a detailed report, in which it stated that the traffic problem was growing serious and strongly recommended that something be done. Acting upon this recommendation, a new Traffic Commission was instantly formed, which set to work at once on an exhaustive investigation of street conditions in New York City during the next 25 years. These two reports will then be placed side by side, and the winner will probably be invited to the Pacific coast, where it will compete with the Los Angeles Traffic report for the All-American report title, at present held by the Navy Investigation Board functioning at the City of Washington.

Awaiting this final solution to the whole problem, the police have instituted what is known today as the One-Way Street. According to this plan, the traffic in the even (or else odd) numbered streets moves steadily west, while the traffic in the odd (even?) numbered streets proceeds steadily east, the plan being that, with two lines of cars continuously advancing in either direction, one will fall with a splash into the East River and one into the Hudson, thus disposing of hundreds of cars nightly.

This One-Way plan is ideal for anyone on a westbound street who has been spending the afternoon on Avenue A and wants to get home to Tenth Avenue. On the other hand, if he lives on Avenue A and has been spending the afternoon on Tenth Avenue, he proceeds home across the State of New Jersey, thence as rapidly as possible through Ohio, Illinois and the Middle West, until he crosses the Rockies and reaches San Francisco, where he embarks on a steamer to the Orient, passes through Asia and Europe, stopping off at points of interest along the way, and finally sets sail from Cherbourg on the Berengaria, arriving in New York Harbor on Christmas Day amid the cheering thousands who line the shore, tossing their hats in the air and strewing his path with roses, as he makes his way through the reporters to the side of his aged mother.

The problem of parking a car in the theatrical district was not solved so easily. In the old days, of course, people could leave their cars parked somewhere up around Poe Cottage in Fordham and then walk to their theater in Times Square with comparative ease. The recent growth of the city, however, has increased distances so much that it has rendered this plan impracticable. In an attempt to solve the difficulty, the Traffic Commission held a luncheon at the Hotel Astor with a number of automobile builders; and after considerable thought and mutual consultation, in which various suggestions were viewed from all angles and each member voiced an opinion, it was finally decided that they would all simply order the consommé and the roast prime ribs of beef with dish gravy, and split the check seven ways.

Conversation then drifted around to the question of where to park a car in the theatrical district; and a prominent manufacturer named Meebles suggested that it would be a good thing if someone would build cars with runways up the back, so that other cars could climb on top and park there. Murgatroyd, of the Murgatroyd Electrics, pointed out on the other hand that if the bottom car moved out first, it would be very difficult for anyone to climb up to the second car without a ladder; and the luncheon disbanded with laughter and considerable chaffing and Meebles paid the check. At present the Commission is waiting for someone to invent a portable parking space; and so the question remains just about where it was.

Meantime the constant ebb and flow of New York City's millions upon millions is being competently governed by strict police regulations, depending on a number of conditions, such as Wall Street closing conditions, weather conditions along the mid-Atlantic seaboard and the condition of your Aunt Kate. Consequently these regulations are usually left to the individual discretion of the policeman on the beat, who is shifting nightly to another beat, involving an entire new set of rules. It is the duty of every loyal citizen to familiarize himself thoroughly with these rules, to cooperate with the police and prevent congestion in the streets.—Corey Ford in *The New Yorker.*

Cylinder-Temperature Control by Evaporation

By A. G. HERRESHOFF[1]

ANNUAL MEETING PAPER *Illustrated with* CHARTS AND DRAWINGS

ABSTRACT

ANY cooling-system is, in reality, a cylinder-temperature control-system. The best operating-temperature depends upon fixed physical-characteristics of metals, oils and gases. The advantages of a fixed temperature of 212 deg. fahr. under all operating and weather conditions are: Reduced piston-friction, better vaporization, elimination of crankcase-oil dilution and prevention of rusting, thereby increasing the life of the engine. A method of determining the cylinder-wall temperatures is described and a comparison of the temperatures for water and for steam-cooling under various operating-conditions shows that, with steam-cooling, the hot-spots are no hotter and the cooler parts of the cylinder have a more nearly uniform higher-temperature.

A description of the Rushmore steam cooling-system is given, together with the reason for the design of each part and a method of calculating its size. No change is necessary in the cylinder-block, the water-pipes are of very small size, the steam-pipe is about the same size as for water-cooling, the radiator core is capped and vented for steam distribution, a drain from the upper tank to the lower tank of the radiator permits running with the radiator full of water, the lower tank is enlarged for reserve water-supply, the air relief-valve has no function while the engine is running and the water-pump must have stainless-steel gears and shafts and be located below the reserve water-tank.

A simple and effective steam-heater for the body is supplied by small pipes and the amount of heat is constant whenever the engine is running. A hot-water-jacketed oil-pan can be used to control the temperature of the oil, thereby preventing the accumulation of diluent in winter and cooling the oil in extreme conditions in summer. The author states that engines of the future will be steam-cooled and covered with an insulating jacket to prolong greatly the cooling-off time after the engine has stopped.

THE function of the so-called "cooling-system" of an internal-combustion engine is to maintain the cylinders at or near some desirable temperature by the removal of heat. The desirable temperature is dictated by conditions of lubrication, vaporization, expansion of the metal, and gas temperature. Tests to determine the effect of varying the jacket-temperature on maximum brake horsepower, full and part-load economy and crankcase-oil dilution indicate that a temperature of 212 deg. fahr. or slightly more is desirable. It is obviously impossible to make any water cooling-system operate at this temperature and, even with the use of thermostatically controlled valves and shutters, it is very difficult to build a water cooling-system that will maintain a truly constant temperature anywhere near this figure under all conditions of load and weather.

The constant temperature at which steam is formed and the immense amount of latent heat required afford the simplest natural means of accomplishing the desired results. It also is obvious that if anything like a fixed temperature is to be maintained at small loads under winter conditions, no form of cooling-system in which large quantities of water are exposed to the cooling-surface will be of any practical value. In other words, all the heat removed must be in the form of latent heat or the system must be 100 per cent steam-cooled. The best results from any mechanical device can be obtained only by designing for them. No compromise of the principles involved can be tolerated, to adapt the system to existing engines or make the system operative by more than one method. When electric lighting was first used on automobiles, the greatest difficulty was to get a satisfactory drive for the generator and the lamps were made so that oil, acetylene or electricity could be used. If the same amount of energy had been spent in developing a fundamentally correct system in the first place, many costly failures would have been avoided.

In a water cooling-system, if we try to increase the efficiency by raising the temperature of the water, just as it gets to a desirable temperature, when steam is being formed at the hotter parts, the system becomes inoperative from its failure to condense steam. If we try to operate a thermostatically controlled water cooling-system at 185 or 195 deg. fahr., a considerable quantity of water will be lost from uncondensed steam, and the heat storage in the water is so limited that the system fails on the first application of a heavy load for any long period. The advantages of maintaining a fixed temperature of 212 deg. fahr. in the jacket under all conditions are well known and can be listed as (*a*) reduced piston-friction, (*b*) better vaporization, (*c*) elimination of crankcase-oil dilution by fuel and water, and (*d*) elimination of cylinder-wall rusting.

The reduction of piston friction with an increase in cylinder-wall temperature has been given by the National Physical Laboratory, England, as from 50 to 70 per cent when the temperature is raised from 122 to 212 deg. fahr. As the piston friction constitutes from 50 to 60 per cent of the total engine-friction, which may be taken as 10 per cent of the indicated power at full load on low speed and 20 per cent of the indicated power at full load on high speed, the expected increase in efficiency for this rise in temperature will be, for full load at high speed, $0.60 \times 0.55 \times 0.20 = 6.60$ per cent; for full load at low speed it will be $0.60 \times 0.55 \times 0.10 = 3.30$ per cent. But, for average driving-conditions, or one-quarter load, the increase in efficiency should be, for high speed, $0.60 \times 0.55 \times 0.20 \times 4.00 = 26.40$ per cent and, for low speed, $0.60 \times 0.55 \times 0.10 \times 4.00 = 13.20$ per cent. The fuel saved in actual driving with jackets at a temperature of 212 deg. fahr. is from 15 to 20 per cent, which corresponds very closely with the expected saving.

Better vaporization is amply demonstrated by the increased acceleration and the absence of crankcase-oil dilution by unburned fuel. The relation of crankcase-oil dilution with fuel and water to cylinder-jacket tempera-

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ture has been shown by the work of the Bureau of Standards and by A. L. Clayden, Neil MacCoull and others. Cylinder-wall rusting can be shown to take place almost entirely after the engine has stopped, with cold jackets.

An investigation of the heat-flow through the cylinder-walls will show that, when under full load, the conditions in the cylinder-jacket with so-called water-cooling or steam-cooling are very nearly the same. Under part-load or average conditions the temperatures are much less with water-cooling; whereas, with steam-cooling, but little change is noticed. To establish actual temperatures, the rate of heat-flow must be known. The average heat-flow in British thermal units per square inch per minute obtained by dividing the known jacket heat-loss by the area exposed to the cooling water or wetted surface is, in typical engines, as stated in Table 1. Heat passing

TABLE 1—AVERAGE HEAT-FLOW

	Engine		
Details	6-Cylinder Passenger Car	6-Cylinder Motorcoach	12-Cylinder Aircraft
Valve Position	In Head	L-Head	In Head
Brake Horsepower	51	92	415
Heat Loss, B.t.u., per min.	2,500	7,400	10,700
Surface, sq. in.	540	1,150	2,520
Average Heat-Flow, B.t.u. per sq. in. per min.	4.6[a]	6.4[a]	4.3[a]

[a] A fair value for heat-flow is 5 B.t.u. per sq. in. per min.

from the combustion-chamber to the jacket must pass through a gas-film, an oil-film, the cylinder-wall and, in some cases, a water-film as well as carbon and scale-films.

Extensive investigations to determine the temperature-drop through the water-film have been made in connection with surface-condenser, boiler and internal-combustion-engine design. The amount of temperature-drop varies almost directly with the rate of heat-flow, roughly as the reciprocal of the water velocity and is reduced irregularly as the water-temperature is increased until active boiling takes place on the hot side of the film. For the average conditions in a cylinder-jacket, this temperature-drop is in the neighborhood of 20 or 25 deg. fahr., although it may be more at points of greater heat-transfer. The temperature of the cylinder-walls will increase roughly with an increase in water-temperature until it

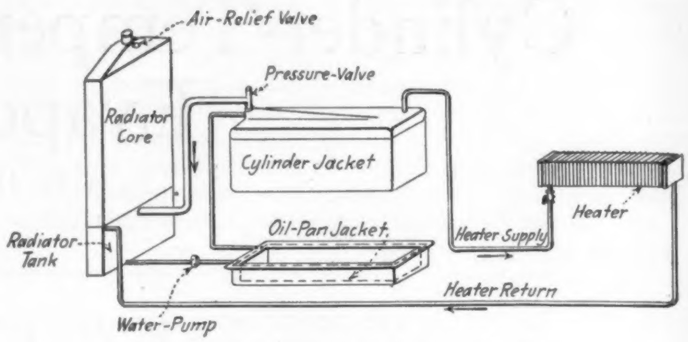

FIG. 2—RUSHMORE STEAM COOLING-SYSTEM
The Diagram Shows the Radiator Core, the Air Relief-Valve and the Radiator Lower-Tank Enlarged To Carry Reserve Water, together with the Oil-Pan Jacket and the Body-Heater. The Water Flows to the Gear-Pump and Is Pumped through the Oil-Pan Jacket into the Cylinder-Jacket, Where It Is Converted into Steam. The Pressure-Valve Is Set To Open at a Pressure of 1 or 2 Lb. Per Sq. In. The Steam Formed Up to That Pressure Goes through the Body-Heater, Thus Heating the Interior of the Body Very Quickly

has reached 185 or 190 deg. fahr., when no further rise in the cylinder-wall temperature will occur so long as the heated surface is wet with water or foam. If the body of the water is cold enough, the steam formed at the hot surface is condensed in the water before it can escape at the top of the radiator.

The formation of steam and its condensation are shown plainly in the illustrations. The three graphs in Fig. 1 show the temperature-gradient through the cylinder-wall with various conditions of heat-transfer and temperature of cooling-water, assuming a cast-iron cylinder-wall 1/4 in. thick and an oil-film 0.0005 in. thick. The effect of carbon or of lime deposits is not shown as their thickness is indefinite; however, a coating of either of these materials 1/32 in. thick may cause an increase of inner-wall temperature of some 200 deg. fahr.

The evolution of steam at the heated surface sets up violent circulation, as the steam imparts kinetic energy to the water by displacement. Some idea of the activity can be had when we consider that steam occupies 1600 times the volume of water from which it is generated. The action is very similar to the discharge of small quantities of explosive at the heated surface. Except for this automatically induced circulation, steam boilers could not operate. The Rushmore steam cooling-system is shown in Fig. 2.

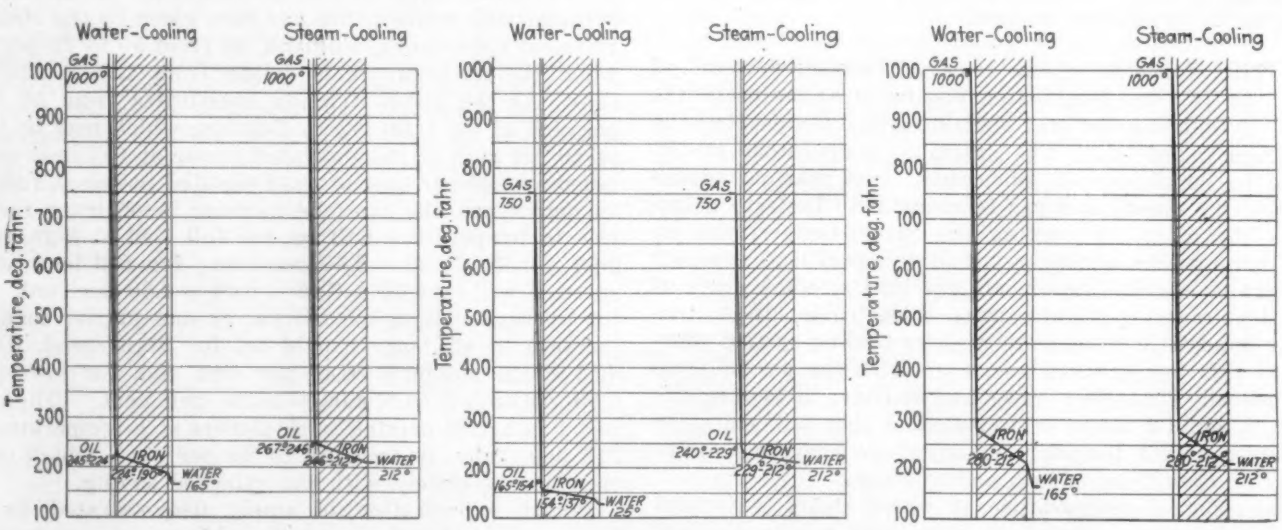

FIG. 1—FORMATION OF STEAM AND ITS CONDENSATION
The Three Portions Show the Temperature-Gradient Through the Cylinder-Wall. Heat-Transfers (Left to Right) of 5.0 2.5 and 10.0 B.t.u. per Sq. In. per Min. and Various Temperatures of the Cooling-Water, Assuming a Cast-Iron Cylinder-Wall 1/4 In. Thick and an Oil-Film 0.0005 In. Thick

The law of heat-transfer from a heated surface to a liquid is stated by Osborne Reynolds as follows:

> The heat carried-off by any fluid from a surface is proportional to the rate at which particles or molecules pass backward and forward from the surface to any given depth within the fluid and depends upon two things, (*a*) the natural internal-diffusion of the fluid when at rest and (*b*) the eddies caused by visible motion which bring fresh particles into contact with the surface. However, the generation of steam at the heated surface radically changes this law, as the heat is now absorbed in changing the water into steam *at the heated surface* and does not need to be transferred to the somewhat removed body of the water.

Cylinder-Block

The normal cylinder-block and water-jacket designed for water-cooling are used, as the conditions in the jacket are much the same in both cases. Naturally, the necessary provisions for successful water-cooling must be retained, such as thorough jacketing of the valve-seats and free water-passages from the cylinder-jacket to the head-jacket as well as no air-domes or large spaces in which air can gather and exclude water. If much more water is pumped than is evaporated, the excess water flowing out with the steam will cause a back-pressure at higher loads, with corresponding temperatures so that the temperatures will vary a few degrees with the load instead of being constant. On the other hand, it is necessary to pump at least as much water as can possibly be evaporated; so, the pump should be more or less proportioned to the size of the engine. To determine the pump size, it is necessary to know how much water is evaporated. This can be calculated from the heat-loss to the cylinder-jackets. A fair average for the various types of cylinder is as stated in Table 2. This information is also presented graphically in Fig. 3.

TABLE 2—HEAT-LOSS TO THE CYLINDER-JACKETS

Type of Cylinder	Heat-Loss, B.t.u. per Min. per B. Hp.	Water Evaporated, Lb. per Min. per B. Hp.
Aviation	30	0.03
Valve-In-Head	50	0.05
L-Head	70	0.07
T-Head	80	0.08

Water-Inlet to Cylinder-Jacket

The small quantities of incoming water is at a temperature of about 200 deg. fahr. and, therefore, very little heat, about 2 B.t.u. per hp. per min. only, is required to bring it to the boiling-point. Heating the water to the boiling-point requires one-thirtieth of the heat absorbed, so the position of the inlet causes little difference in the temperature of the cylinder. The water is put in near the top of the block so that the jacket will not drain through the pump after the engine has stopped.

If the water-inlet is placed near the steam-outlet, but not so that the water will be carried off by the out-going steam, the cylinder-block will heat-up much more quickly from cold because the fresh water pumped-in will flow out through the steam outlet-pipe without causing any circulation in the jacket. In starting, only stagnant water in the jacket needs to be heated, instead of heating all the water in the system, before the cylinders are at their operating temperature.

To guarantee that the cylinder-block always will be full of water, it is necessary to pump more water than ever can be evaporated; in practice, it has been found desirable to pump two and one-half times the maximum

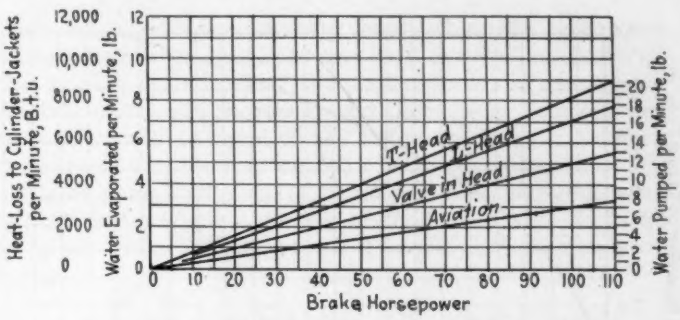

FIG. 3—VALUES OF HEAT-LOSS TO THE CYLINDER-JACKETS

To Determine the Size of the Water-Pump, It Is Necessary To Know How Much Water Is Evaporated. This Can Be Calculated from Known Values of the Heat-Loss to the Cylinder-Jackets, Average Values for Which Are Stated in Table 2 for Various Types of Cylinder

evaporative-requirements. The water-pipes should be large enough to carry this quantity of water without undue pressure-drop or at a velocity exceeding 6 ft. per sec. The minimum inside-diameter is then calculated as follows, and also is calculated in Fig. 4.

$$d = \sqrt{[(4 \times 28.8\, W_p)/(60 \times 6 \times 12\pi)]} = \sqrt{0.0085\, W_p} \quad (1)$$

where

d = the minimum-diameter of the water-pipe in inches

W_p = the weight of water pumped in pounds per minute

28.8 = the volume in cubic inches of 1 lb. of water at 212 deg. fahr.

In cases where two or more cylinder-blocks are served by one pump, the water must de distributed to the blocks equally. This can be done by using a fairly large pipe from the pump to the point of distribution and smaller-pipes or orifices of equivalent diameter to each block, so that a pressure of about 3 lb. per sq. in. is built-up at the point of distribution, which results in an equal flow irrespective of any slight pressure-variation between the blocks.

Steam-Outlet from the Cylinder-Jacket

The steam-outlet from the cylinder-jacket must be at the top, so that water will remain in the jacket. As the entire top of the jacket contains a mass of seething foam, the position of the outlet in the front or center makes little difference. The steam-pipe should be large enough to prevent any undesirable pressure-drop in the

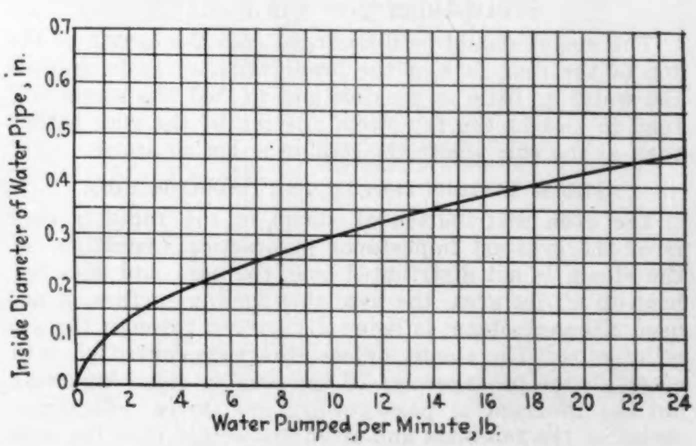

FIG. 4—MINIMUM INSIDE-DIAMETER OF WATER-PIPES

To Guarantee That the Cylinder-Block Always Will Be Full of Water, It Is Necessary To Pump More Water Than Ever Can Be Evaporated. In Practice, It Has Been Found Desirable To Pump Two and One-Half Times the Maximum Evaporative-Requirement. The Water-Pipes Should Be Large Enough To Carry This Amount of Water without Undue Pressure-Drop or at a Velocity Exceeding 6 Ft. Per Sec.

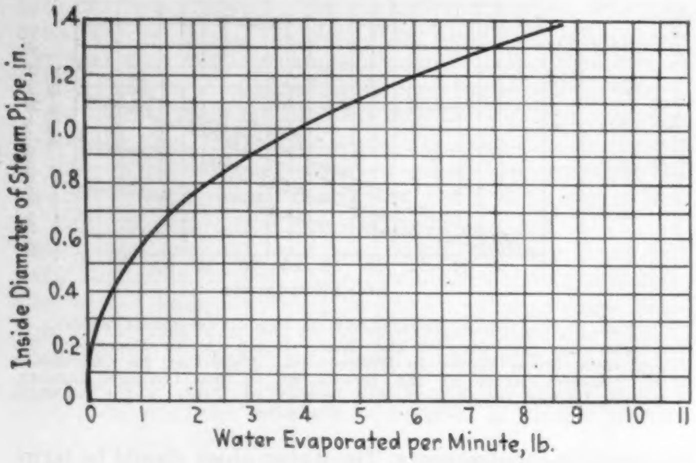

FIG. 5—MINIMUM INSIDE-DIAMETER OF STEAM-PIPES
The Steam-Pipes Should Be Large Enough To Prevent Any Undesirable Pressure-Drop in the Pipe-Line; Say No More Than about 1 Lb. Per Sq. In. at Full Load. The Minimum Inside-Diameter Is Calculated from the Formula for the Flow of Low-Pressure Steam through Pipes

pipe-line; that is, of more than about 1 lb. per sq. in. at full load. The minimum inside-diameter can be calculated from the formula for the flow of low-pressure steam through pipes, as follows, and is also calculated in Fig. 5.

$$\begin{aligned} d &= \sqrt[5]{(LW_e^2)/(pwc^2)} \\ &= \sqrt[5]{(4\,W_e^2)/(0.037 \times 40^2)} \\ &= \sqrt[5]{(0.0676\,W_e^2)} \qquad (2) \end{aligned}$$

where

c = a constant varying with the pipe size of from ¾ to 1¼ in., which is equal to 0.40

d = the minimum inside-diameter of the steam-pipe in inches

L = the length of the steam-pipe, with an allowance in feet for bends, which is equal to 4 ft.

p = the pressure-drop in pounds per square inch, which is equal to 1 lb. per sq. in.

w = the weight of steam in pounds per cubic foot, which is equal to 0.037 lb. per cu. ft.

W_e = the number of pounds of steam evaporated per minute

Although the excess water pumped, passing out with the steam, has only 0.001 the volume of the steam, its effect on the pressure-drop on passing bends can be very noticeable. Therefore, all bends should be of long radius and free.

STEAM-INLET INTO THE RADIATOR

The steam should be discharged into the center of the top of the rear face of the lower tank, so as to disturb the water as little as possible and so that the steam will tend to rise in the fan-swept portion of the core rather than at the side where the cooling is not so active.

STEAM DISTRIBUTION IN THE RADIATOR CORE

The even distribution of steam in the radiator core is of the greatest importance in practical operation. If the steam is not distributed over the core and does not heat-up all its area, the available cooling-surface is not used although steam is being discharged through the air relief-valve. The steam, unless otherwise controlled, will enter all the passageways of the core in equal volumes; but, as the central passageways are more effectively cooled by the fan-blast and often are longer than the side passageways, the steam in the center will be condensed before reaching the top, leaving a cold section, while the side passageways, not being able to condense all the steam entering them, will allow steam to flow into the upper tank. Some of this steam in the upper tank will flow down the top of the center passageways and trap air in the portion of the core in front of the fan; but this condition can be prevented by restricting the flow of steam from the top of the side passageways. This is accomplished by placing caps over the tops of groups of tubes. In practice, it has been found sufficient to cap the side passageways in two or three groups on each side, the caps being of a size to cover one-quarter of the width of the radiator on each side, as shown in Fig. 6.

Each cap is drilled with a vent-hole 3/32 to 1/16 in. in diameter which will allow air to escape from that section of the core but will set up enough resistance to the passage of steam so that the steam will have a tendency to pass through the central or well-cooled portion of the core.

UPPER-TANK DRAIN

When the water-passages in the core are very fine, the rising steam, under heavy load, will carry some of the condensed water to the upper tank and hold it there until the load falls-off, unless a drain to carry off the accumulated water is provided. Such a drain leading from the bottom of the upper tank to the bottom of the lower tank will drain the former completely and, as its outlet is always submerged in the lower tank, no steam can pass through the drain. If the drain pipe is made large, say of ½-in. diameter for a 30-hp. engine, the steam cooling-system can be operated with the radiator completely filled with water, the only objection being that the steam, passing up through the comparatively cool water in the core passages, causes a muffled crackling sound; but this may not be a disadvantage on truck or industrial engines where it is always desirable to have a large supply of reserve water.

RESERVE WATER-TANK

The radiator lower-tank besides containing the reserve water necessary to make up for water lost at the pump or pipe fittings, must be of sufficient capacity to supply water to fill the body heating-system without running the water-level below the pump-suction. In practice, 1 gal. for each 25 hp. has been found ample in normal cases. In future designs it will be possible to obtain the desired reserve capacity in the oil-pan jacket, thus permitting a radiator of large area with a thin efficient core.

PUMP-INLET

The water-pump inlet-pipe connecting the reserve tank to the pump should be of the same size as the pump discharge and should be a soft-copper tube or a rubber hose to allow for relative movements of these units. The water-outlet in the reserve tank should be fitted with a coarse screen or be placed about ½ in. above the bottom of the tank to prevent drops of solder or other foreign matter from entering the pump.

AIR RELIEF-VALVE

An opening should be provided to allow air to enter and to escape from the top of the radiator, just as an air-valve is fitted to a heating radiator in a building. Steam cannot enter if the passages of the radiator are filled with air; hence, no cooling can take place. With a vent in the top, the steam entering the lower part of the passages will force the air up and out despite the fact that cold air is twice as heavy as steam.

A lightly loaded valve is used instead of a plain opening. The valve-seat has a slot to permit a slight in-and-out flow of air without forming pressure or a vacuum. The sole purpose of the valve is to prevent a heavy momentary puff of steam after the engine has stopped,

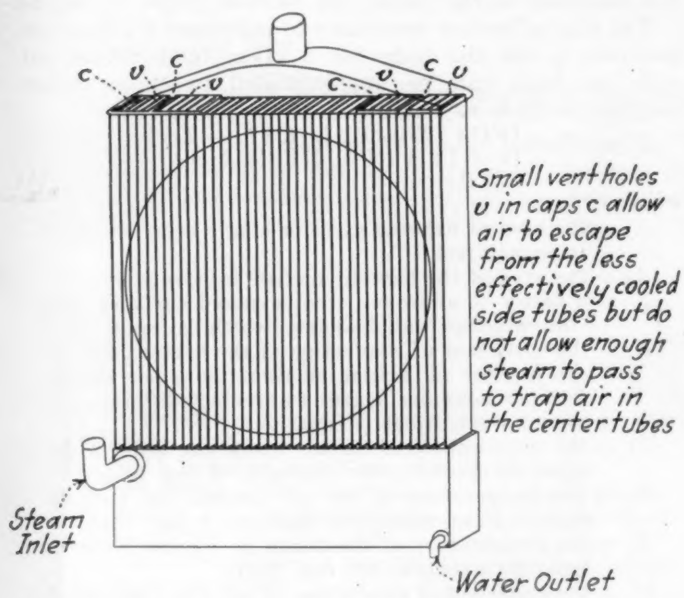

FIG. 6—RADIATOR-TUBE CAPS AND VENTS

To Prevent Steam in the Upper Tank from Flowing Down the Central Passageways and Trapping Air in the Portion of the Core in Front of the Fan, the Flow of Steam from the Top of the Side Passageways Is Restricted by Placing Caps over the Tops of Groups of Tubes. In Practice, It Has Been Found Sufficient To Cap the Side Passageways in Two or Three Groups on Each Side, the Caps Being of a Size To Cover One-Quarter of the Width of the Radiator on Each Side, As Indicated. Each Cap Has a $\frac{1}{16}$ to $\frac{3}{32}$-In. Vent-Hole, Which Will Allow Air To Escape from That Section of the Core but Will Set-Up Enough Resistance to the Passage of Steam So That the Steam Will Have a Tendency To Pass Up through the Central or Well-Cooled Portion of the Core

immediately after pulling a heavy load. At this time, with the pistons and exhaust valves giving up their heat and with no fan-blast to condense the steam, a puff of escaping steam for 20 or 30 sec. would be seen. The loss of water would be insignificant, but the moral effect would be bad. The valve prevents a momentary puff of steam and will not allow pressure to build-up to more than 1 lb. per sq. in. The valve has nothing to do with the working of the system. It should be large enough to permit the free discharge of all the steam formed in the event of breaking of the fan belt or other extreme condition; say one-third the diameter of the steam-pipe.

WATER-PUMP

In a steam cooling-system, the duties of the water-pump become those of a feed-pump on a steam boiler. The pump must be positive in its delivery under all conditions. The delivery, although small, should roughly be in proportion to the engine speed, but the pressure against which it works is never more than a few pounds per square inch. The only types of pump that will fulfill these conditions are plunger-pumps and gear-pumps. The gear-pump is used, being much simpler, cheaper and easier to keep tight.

It is necessary to have the pump below the reserve water-tank because, even if all air could be excluded, the maximum possible lift is very limited with hot water, as the water boils when the pressure is reduced. Placing the pump just below the bottom of the reserve tank has been found to provide sufficient head for all conditions.

With a pump made large enough to supply two and one-half times the evaporative requirements at maximum power, ample water for conditions of full load when the engine speed has been reduced in a greater ratio than has the amount of horsepower will be available.

The capacity of the gear-pump can be calculated from the volume of the space between the teeth of the gears. This space, although slightly larger than the teeth, can be assumed to be equal to one-half the volume between the outside cylinder and the root cylinder of the gears. As two gears are working, the theoretical delivery per revolution will be equal to the difference in area between the outside and the root circle of one gear times its width. Tests of pumps running at from 1500 to 2000 r.p.m. with boiling water show that the actual delivery is from 20 to 30 per cent of this amount, the formula for calculation being

$$W_p = 0.25 \times 0.0346\frac{\pi}{4}\,(D^2 - d^2)\,FN$$
$$= 0.0068\,(D^2 - d^2)\,FN \quad (3)$$

or

$$147\,W_p/N = (D^2 - d^2)\,F \quad (4)$$

where

d = the root diameter of the gear in inches
D = the outside diameter of the gear in inches
F = the width of the gear in inches
N = the number of revolutions per minute of the pump gears
W_p = the water pumped in pounds per minute
0.0346 = the weight of 1 cu. in. of water at 212 deg. fahr.

As the leakage through the pump is mostly past the ends of the gears, it is best to make the gears of wide face and small diameter or as nearly so as conditions will permit. With straight-tooth gears, the filling of the space

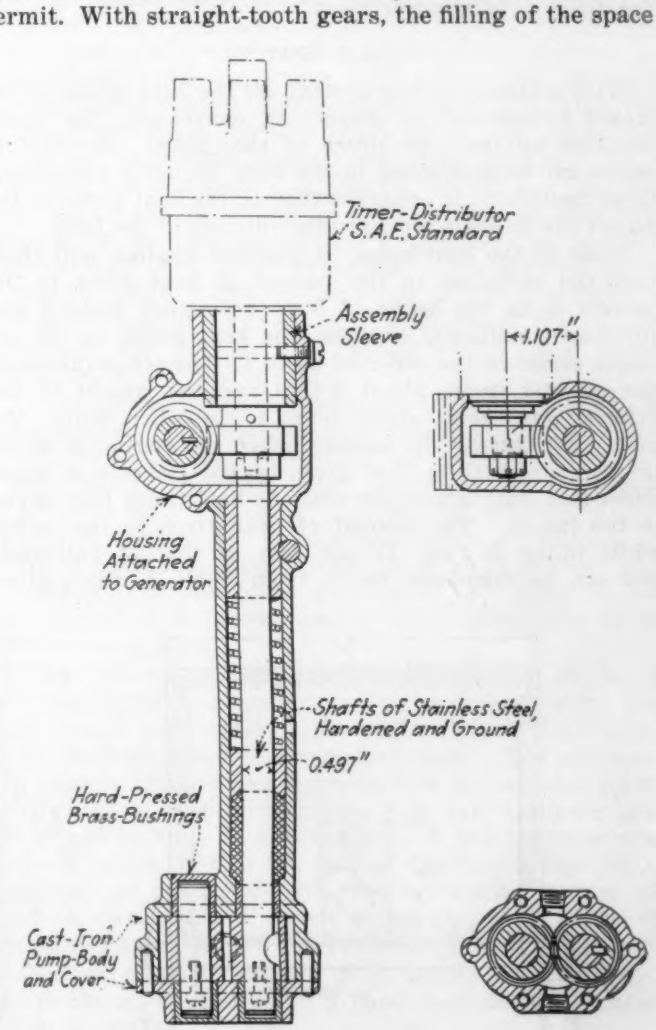

FIG. 7—DESIGN OF THE WATER-PUMP

A Typical Water-Pump Design, in Which the Pump Is Driven from the Timer-Distributor Gears and Mounted on the Generator, Is Shown. This Design Places the Pump Low, Has No Flexible Couplings, Has a Spring-Compressed Stuffing-Box, Is Cheap To Make, and Will Swing with the Generator for Timing-Chain Adjustment

between the teeth as the gears roll apart and the forcing of the water out of the space as the gears roll together is intermittent, resulting in noise and a falling-off of delivery at high speeds. Jamming of the water that is trapped between the teeth and the case, which causes vibration and noise also occurs. These objections can be overcome by using helical gears in which the amount of twist is at least equal to the circular pitch.

Although the quantity of water to be handled is about the same as the quantity of oil pumped in a pressure oiling-system, the conditions under which the gears operate are very different and the design must be modified accordingly; whereas, the lubricating-pump handles a lubricant that is forced to all the rubbing surfaces and the water-pump handles boiling water loaded with iron rust which is an active corrosive and an excellent grinding compound. Soft-steel or bronze gears have been found to be very short lived, while hardened stainless-steel gears and shafts, working in bronze bushings with a bronze or cast-iron case, will outlast the engine. The operator will never know that a pump is used.

A typical design, in which the pump is driven from the timer-distributor gears and mounted on the generator is shown in Fig. 7. This design places the pump low, has no flexible couplings, has a spring-compressed stuffing-box, is cheap to make, and will swing with the generator for timing-chain adjustment.

Steam-Heating

With a steam cooling-system, all the heat given to the jacket is removed by steam; or, conversely, the steam contains all the heat given to the jacket. As all this steam can be condensed in the body by using sufficiently large heaters, it is apparent that all the heat given to the jacket can be transferred to the interior of the body.

Tests of the heat-losses of gasoline engines will show that the variation in the amount of heat given to the jackets is in the order of 5 to 1 between no-load and full-load conditions, whereas, the heat going to the exhaust varies in the order of 40 to 1. The temperature of the exhaust varies about 4 to 1 and the weight of the exhaust gas varies about 10 to 1. In other words, the heat given out by the exhaust when the engine is idling is about one-fifth of that given by the jacket and, when under full load, about one and one-half times that given to the jacket. The amount of heat given to the jacket while idling is fully 15 per cent of that at full load, and can be calculated easily from Table 2 which gives the heat-loss to the jacket for various types of engine.

The size of heater necessary to maintain a given temperature inside the body for a given temperature outside the body can be approximated by using house-heating methods as follows

$$A_h = [FUA\ (T_i - T_o)]/[K\ (T_s - T_i)] = [2 \times 1.2\,A\ (50\text{–}0)]/[2\ (212\text{–}50)] = 0.37\,A_e \tag{5}$$

where

A_e = the area of exposed glass or single layer of metal in square feet
A_h = the area of the heating surface in square feet
F = a factor to allow for other exposed surfaces, and for windage and leakage, which is equal to 2
K = the coefficient of conduction of the heater; that is, the number of British thermal units per square foot per hour per degree Fahrenheit difference in temperature, which is equal to 2
T_i = the temperature of the air inside the body in degrees Fahrenheit; for example, 50 deg. fahr.
T_o = the temperature of the air outside the body in degrees Fahrenheit; for example, 0 deg. fahr.
T_s = the temperature of the steam in degrees Fahrenheit; for example, 212 deg. fahr.
U = the coefficient of conduction of window glass; that is, the number of British thermal units per square foot per hour per degree Fahrenheit difference in temperature, which is equal to 1.2

Heaters made of finned copper-tubes soldered into headers will be light, rust-proof and efficient. The average finned tubing of 3/8-in. outside-diameter with fins of 7/8-in. outside-diameter has 6.6 sq. ft. of heating surface per foot of length. A well-perforated sheet-steel guard is placed over the heater to protect the tubes from mechanical injury as shown in Fig. 8. The heater can be designed to go in the floor or on the floor, to stand against a wall or a seat back or to swing on hinges into a recess when not in use, thereby turning-off the steam automatically. No air-vents or water-traps are necessary, as this system works under a definite flow of steam which will carry any accumulated air or water to the reserve water-tank in the main radiator.

The heater-pipes should be large enough to carry all the steam the heaters can condense without an excessive pressure-drop in the line. The quantity of steam, W_h, necessary for a heater can be computed easily as follows, this being the number of British thermal units divided by 972; or,

$$W_h = [Kd(T_s - T_i)]/(972 \times 60) = (2d \times 162)/(972 \times 60) = d/180 \tag{6}$$

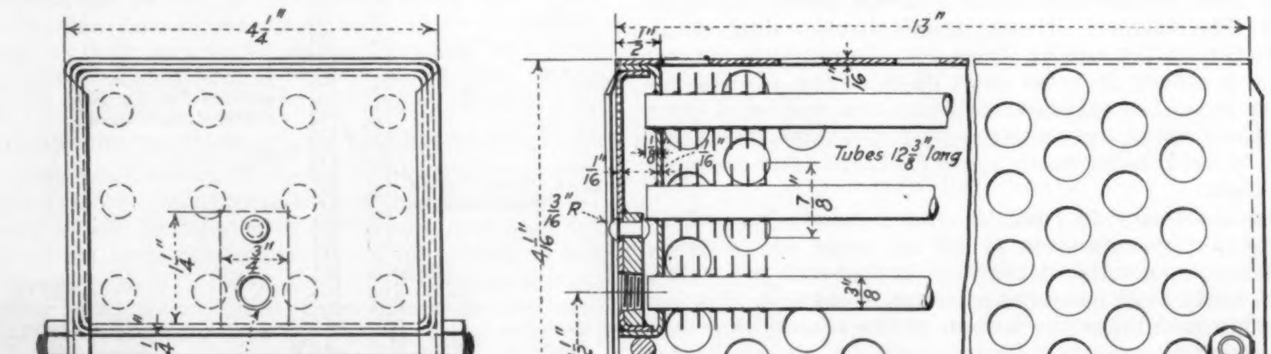

Fig. 8—Perforated Sheet-Steel Body-Heater Guard
This Guard Is Placed over the Body-Heater To Protect the Tubes from Mechanical Injury

where

$K = 2$

$T_i = 50$ deg. fahr.

$T_s = 212$ deg. fahr.

$W_h =$ the pounds of steam per minute needed to supply the heater

The size of the heater-pipes can be calculated for a pressure-drop of ½ lb. per sq. in. from the formula for the flow of low-pressure steam as follows, and is calculated also in Fig. 9.

$$d = \sqrt[5]{(LW_h^2)/(pwC^2)}$$
$$= \sqrt[5]{(10W_h^2)/(0.5 \times 0.043 \times 30^2)}$$
$$= \sqrt[5]{0.52W_h^2}$$

where

$C =$ a constant, depending upon the pipe sizes; for ½-in. pipe it is equal to 30

$d =$ the inside diameter of the pipe in inches

$L =$ the length of the supply pipe in feet to the nearest heater, with an allowance for bends, which is equal to 10 ft.

$p =$ the pressure-drop in pounds per square inch, which is equal to 0.5

$w =$ the weight of steam in pounds per cubic foot, which is equal to 0.043

As the average sedan-body requires pipe of only 5/16-in. inside-diameter and as copper tubing or rubber hose can be used, the piping is a simple and inexpensive matter. Either individual valves on each heater or a single valve placed anywhere in the supply line can be used to regulate the heat-supply. If a single valve is fitted, it can be placed in the pipe near the rear of the cylinder-block and have the valve-stem extend to the instrument board. The heater supply-pipe should be connected to the top of the jacket so that it will be supplied with steam rather than with water, and from the rear of the cylinder-head to reduce the length of piping to the minimum. The piping can run either in the body or under the floor. No particular care need be taken to have the piping run level or to have it drain. Alcohol added to the cooling-system also passes through the heating-system; therefore, not as much possibility of freezing exists as in the radiator. To produce a definite flow of steam through the heating-system, a pressure of 2 or 3 lb. per sq. in. is required.

A pressure-valve fitted on the cylinder-block at the steam-outlet maintains this pressure by shutting-off the flow of steam to the main radiator until the desired pressure has been reached, when the spring-loaded valve opens and allows water or steam not used by the heating-system to pass through the main steam-pipe to the radiator, where it is condensed. Any steam not condensed by the heater is delivered to the reserve tank by the heater return-pipe, where it is condensed in the main radiator. In this way, the heater is supplied with all the steam it can use, before any heat is dissipated in the radiator.

The pressure-valve is nothing more than the familiar reducing-valve designed to open at a pressure of 2 or 3 lb. per sq. in. The valve should be made so that the pressure for full opening is very little more than for first opening, by using a long flexible-spring. The area through the valve when open should be at least as large as the area through the steam-pipe.

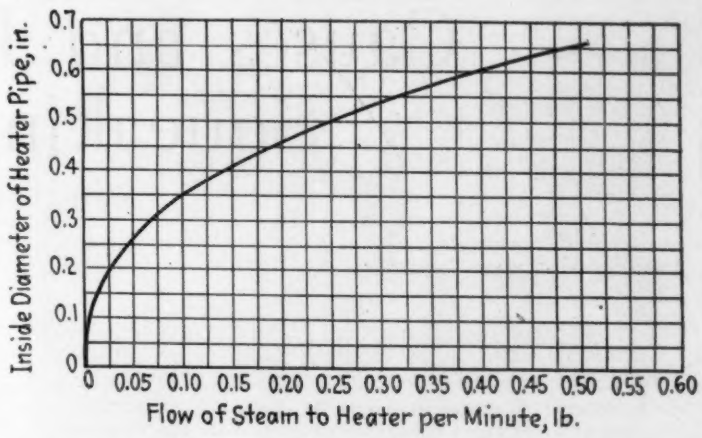

FIG. 9—MINIMUM INSIDE-DIAMETER OF BODY-HEATER PIPES
The Size of the Pipes to the Body-Heater Is Calculated for a Pressure-Drop of ½ Lb. Per Sq. In. from the Formula for the Flow of Low-Pressure Steam in Pipes

OIL-PAN JACKET

The temperature of the lubricating oil has a marked effect upon the efficiency and life of the engine. An increase in temperature of the crankcase oil has nearly as great an effect on the engine friction as a like rise in the temperature in the engine-cylinder jacket. A constant engine-cylinder jacket-temperature of 212 deg. fahr. practically will prevent crankcase-oil dilution under all operating conditions; but, during the warming-up period in winter, dilution takes place at a high rate and, if the diluent is not driven-off, it will accumulate until an undesirable amount has been reached. As in the original distillation of the oil, the lighter fuel and the water can be driven-off by heating. In this case, the vapor so released passes-off through the breather or through the intake-manifold. An oil-pan jacket through which water at from 190 to 210 deg. fahr. is being circulated will, at light loads, heat the oil and drive-off the diluent; but, under heavy loads in hot climates, it will cool the oil.

On road-tests, the temperature of the crankcase, as determined by a distance-type thermometer suspended at the level of the crankshaft, has been found to vary from 170 to 205 deg. fahr., depending upon weather and upon load conditions. In winter weather, an average of 5 miles will be needed for the oil to reach its normal operating-temperature. The oil-pan-jacket pipe-connections should be at the top of the jacket so that no air-pocket is formed and be of the same size as the water-pump pipes.

The reduced oil-flow resulting from cold oil in the normal circulating-system can be provided for by placing the oil relief-valve on the end of the oil distributing-line farthest removed from the pump. The resistance to oil-flow through the bearings will be balanced by the resistance to flow through the line, and a higher pressure will be built-up automatically at the bearings when the oil is cold. With the lead-off for the oil-gage placed adjacent to the relief-valve, the increased pressure will not be recorded and cannot injure the gage. Like the engine-cylinder jacket, the function of the oil-pan jacket is not so much to remove or to supply heat as it is to keep the oil constantly at a fixed desirable-temperature.

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Causes and Prevention of Squeaking Brakes

By F. C. STANLEY[1]

ANNUAL MEETING PAPER *Illustrated with* PHOTOGRAPH

ABSTRACT

TESTS show that scratching of the brake drum by brass wire in the brake-lining, high rivet-heads, particles of steel from the drum or grit from the road sets up vibrations in the drum and that the note given out by these vibrations is of the same tone as the ringing note produced by striking the undamped drum with a hammer. The sound can be damped or muffled by applying slight pressure to the drum at a point diametrically opposite the initial point of vibration.

From these observations the theory was formulated that brake squeaking is the undamped or unmuffled vibration of the drum caused by the plowing action of metal or grit in the lining. This theory explains the success of various methods that are used for remedying squealing brakes, which methods are enumerated and include lubrication of the lining, use of liners and shims, prevention of metal-to-metal contact by rivet heads, smoothing of the drum face, correction of eccentricity of the drum, truing the brake band for circularity, and applying the internal and external brakes simultaneously.

Preventive measures that can be taken by the car builder are (*a*) making the drums of high-carbon steel, (*b*) assuring true circularity of the bands and (*c*) sinking the rivet heads 1/16 in. below the surface of the lining. If these measures are taken, the adjustment of the brakes to give uniform clearance at all points will result in quiet brakes.

Service-station methods of overcoming squeaking brakes are described, and in the case of badly-worn drums on used cars a very successful remedy is said to be the insertion of thin metal shims under the lining between the rivets. Use of an oily or greasy lubricant is regarded as a dangerous makeshift, as it often leads to the violent seizing of the brakes and serious damage to the car. Nine-tenths of the brake jobs that come to the service-station have no free movement at the external rear anchor-support. This must be eased-up to permit the lining to make contact with the drum at the rear and to act as a damper to vibrations caused by hard particles at the forward area of high pressure. All foreign matter should be removed from between the drum and lining and if the drum is scored it should be smoothed with fine emery cloth. If the band is not truly circular and concentric with the drum, it should be peened to conform to the drum. The perfection of the rounding of the band can be tested by applying the brake and trying to insert a thin feeler-gage between the lining and drum to find a place where the lining fails to grip the drum.

BRAKE squeaks are not confined to any one type of brake nor to any particular brand of brake-lining. They may be heard whenever traffic is checked, and the desire to prevent this noise has increased with the elimination of other noises produced by the automobile. It is probable that the brakes have been relined recently on more cars because of squeaks than because of worn condition of the lining. Nearly every repairman has his pet lining as a remedy for the trouble, and all lining manufacturers are seeking the causes of complaints of brake squeaking and remedies for the nuisance.

Noisy brakes are made silent by the following practices, which are not offered as recommendations, however:

(1) Application to the lining of a mixture of castor-oil and resin-oil, of neatsfoot oil or of dry graphite powder or a mixture of graphite with grease

(2) Flushing the surface of the lining with water

(3) Introduction of rubber or felt between the lining and the brake band, either at the points of highest pressure or as a complete interliner

(4) Use of metal shims at various places beneath the lining

(5) "Rounding" the lined band and fitting it so that it makes contact with the drum on a large proportion of its surface at each application of the brake

(6) Use of a softer lining or of a lining containing no brass wire

(7) Removing grit or embedded particles of steel from the surface of the lining

(8) Removing brass rivet-heads from contact with the drum

(9) Smoothing the surface of the drum

(10) Correcting the eccentricity of the drum

(11) Adjusting the brake band to give uniform clearance around the drum

(12) Simultaneous application of the internal and external brakes

NOISE PRODUCED AS BY PHONOGRAPH

To determine the causes of brake squealing, tests were made with a Carson brake-lining testing-machine, which offers, in a simplified brake, as shown in Fig. 1, a means for making such a study. As only a small area of lining is in contact with the surface of the drum, the drum can vibrate as a whole when scratched against any point on the surface of the lining.

It was found that lining containing no brass wire is uniformly silent and that lining containing brass wire is silent until wear produces metal-to-metal contact. Squeaking is then produced by the plowing action of a bit of wire in a furrow or while making a furrow in the face of the drum. This noise can be stopped by (*a*) slightly changing the position of the shoe so that the abrading particle no longer works in the same groove, (*b*) smoothing the surface of the drum with fine emery-cloth, which destroys the furrow, or (*c*) applying pressure to the drum at a point directly opposite the cause of the vibration. All these remedies can be applied without stopping the testing machine, altering its constant power-absorption or in any way changing the amount of surface contact of lining and drum.

After making these tests, the shoe was removed and

[1] M.S.A.E.—Chief engineer, Raybestos Co., Bridgeport, Conn.

the tone produced by striking the drum with a hammer was compared with the tone of the squeak previously produced and was found to be the same note. This tone could be damped or muffled by applying slight pressure to the drum at a point diametrically opposite the point of impact of the hammer blow. Other drums were tested by the same method and in each case the tone produced by ringing the drum with a hammer blow was identical in pitch with that of brake squeak on the same drum. It could be damped by pressure opposite the point of hammer impact but could not be damped by pressure applied elsewhere.

These observations led to the formulation of the following theory of the cause of brake squeak:

> Brake squeak is undamped or unmuffled drum vibration caused by the plowing action of metal or dirt in the brake-lining.

Theory Applied to Facts

Since a theory must explain all facts, let us apply this theory to each of the enumerated means of silencing squeak. The first means (1) introduces lubrication, which stops the cutting action of the abrading particle. Flushing with water (2) removes the particle or decreases the severity of its action as does a lubricant. Introduction of rubber or felt liners (3) damps or muffles the vibration of the drum at its source by providing a compressible-cushion backing for the abrading particle, thus allowing it to be pushed below the surface of contact. The use of metal shims (4) at various points is an attempt to apply pressure directly opposite the abrading particle and thus to muffle the vibrations. Rounding the bands, that is, truing them to circular form, (5) may be expected to muffle vibration completely. Use of a softer lining (6) permits any hard abrading particle to be embedded in the lining, while removing the brass wire, grit or steel particles (7) and brass rivet-heads (8), smoothing the drum (9) and correcting the eccentricity of the drum (10) all prevent or decrease the severity of the abrading action. Adjusting the brake to give uniform clearance (11) muffles drum vibration but is effective only when the band is perfectly circular. The simultaneous application of internal and external brakes (12) assures perfect damping.

It may be predicted that, with localized high-pressure, squealing of the brake will result when an abrading particle is uncovered by wear or introduced from the metal of the drum or as road grit, unless the vibration of the drum is damped by contact of the lining on the side of the drum opposite to the offending particle.

Preventive Measures To Be Taken

It is obvious that the use of lining having no brass wire is not to be considered. Asbestos yarns have exceedingly low tensile-strength and brass wire was introduced to make possible the weaving of the yarn into a compact fabric. A softer lining is less durable and, in use, becomes hard and of decreased thickness, which makes more frequent adjustment necessary.

The embedding of steel particles from the drum can be prevented by using drums of higher carbon-content. Drums of 0.10 or 0.20 per cent carbon score at 750 deg. fahr., whereas, with from 0.40 to 0.50 per cent of carbon, scoring does not occur below about 900 deg. fahr., which is a drum temperature that is seldom reached. Road grit can be mostly excluded by the use of internal brakes or by shields on external brakes. Grit can be removed, however, by flushing.

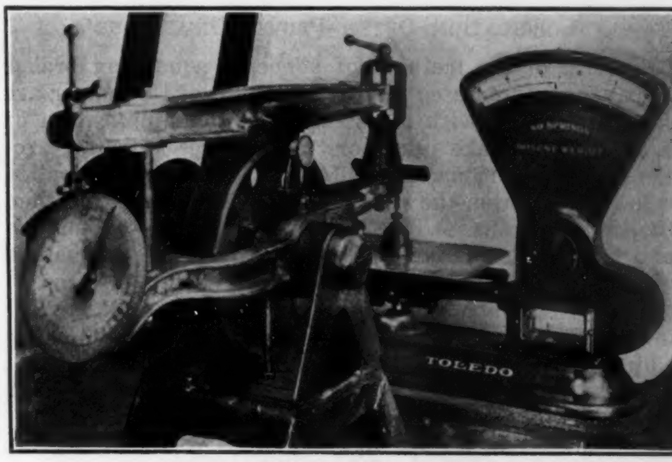

Fig. 1—Carson Brake-Lining Testing-Machine
The Short Section of Lining under the Shoe in the Brake Beam Allows the Drum To Vibrate Undamped. Exposed Brass Wire or a Hard Particle of Steel or Grit on the Face of the Lining Plows a Furrow in the Face of the Drum and Starts the Drum Vibrating. The Tone Given Out by the Drum Is Identical in Pitch with the Ringing Note Produced by Striking the Undamped Drum with a Hammer. The Squealing Produced by the Particle on the Lining Can Be Stopped by Changing the Position of the Shoe Slightly, by Smoothing the Face of the Drum with Emery Cloth, or by Applying Slight Pressure to the Drum at a Point Diametrically Opposite the Cause of the Vibration

Preventive measures that can be taken by the manufacturer, therefore, are (*a*) use of drums of higher carbon-content, (*b*) use of perfectly circular brake bands that will distribute pressure uniformly and (*c*) sinking rivet heads 1/16 in. below the surface of the brake lining.

Service Remedies for Squeaking

The service-station is confronted with the difficult problem of correcting errors made by the car builder, who frequently sends out cars with brake bands that are out of round and with lining rivet-heads that bear on the face of the brake drums. If proper attention is given to these two matters, squeaking brakes can be silenced by adjusting the brakes to give uniform clearance. When this adjustment fails to stop the squeaking, the bands should be removed and examined for rivet heads that rub. After these have been set 1/16 in. below the surface, the band should be trued so that it will grip the drum at all points when applied. Any embedded particles of grit or metal should be removed with a wire brush and the band reassembled.

If the squeaking persists after this treatment, as it will do sometimes, the circularity of the band should be tested by applying the brake and attempting to insert a thin feeler-gage at points all the way round between the drum and lining in an endeavor to find a place where the lining fails to grip. When such a place has been discovered, the band should be peened into shape there.

In case the drum is so badly worn that the band can make no contact on its internal surface, the only remedy is to insert shims beneath the lining between the rivets. For the purpose 12 shims, each 1.000 x 0.75 x 0.25 in., are used on each external brake. It is impossible to damp the vibrations of the drum unless the lining is made to conform to the worn surface of the drum. The use of these tinplate shims with worn drums has proved very successful. The method of inserting them is to freeze-up the band, pry the lining away from the band between the rivets with a screw-driver, insert the long side of the shim parallel with the edge of the band, and then peen to conformity with the drum. As many as 24 shims have been inserted in this way in 15 min.

Lubrication Often Proves Disastrous

Several of the methods of silencing squeaking brakes that were enumerated in the beginning of this paper are frequently used with disastrous results. Application of a lubricant, "brake juice" or "dope" gives temporary relief but has serious after-effects. The material applied collects dust from the road or abraded asbestos and then the lining "grabs." This "grabbing" is often so sudden and hard as to break the axle, shear rivets on housings and strip gears. Sometimes even new lining seizes in this way. In such cases it has been learned that the lining had been applied to a band on which "doped" lining had been used and that the drum had not been cleaned.

Brake-lining manufacturers have expended hundreds of thousands of dollars in developing and testing brake-lining saturants in an attempt to impart to the lining all the qualities that are desirable, and it is unreasonable to expect to add anything more to the lining that will overcome squeaking without losing some valuable quality of the lining.

If the service-man is forced by lack of time or exhaustion of patience to resort to the use of a lubricant, the use of dry powdered graphite is recommended. This will serve as a temporary remedy and dust and grit will not adhere as they do to oil and grease. However, the use of graphite or of rubber shims beneath the lining at points of greatest pressure is regarded as a makeshift that is to be employed only as a last resort and with the expectation that the customer will return within 30 days.

Free Movement at Anchor Necessary

Service-men who do brake work find that about 9 out of 10 jobs that come to them have no movement at the external rear anchor-support; in fact, it is necessary to free-up the anchor bracket on some new cars to permit the lining to make contact with the brake drum at the rear. When the pressure is high at the forward end of the band and absent at the rear of a vertical center-line, damping of the vibration that is produced by abrading particles in the area of high pressure does not occur. Therefore, freeing at the anchor is very important as a means of obtaining silent action and increased efficiency and brake durability.

It is recommended that the car-owner or driver wash the dirt from the brakes occasionally and examine them to make sure that free action at the anchor is restored. Removal of the grit by flushing not only tends to remove one cause of squeaking, but also greatly reduces wear on the drums and linings.

In England a steel band lined with cotton is sold as a device for damping brake-drum vibration to be applied externally to the drums of the Morris car. In this Country we probably should regard such a remedy as worse than the squeak. It is also of interest to know that silent brakes are obtained in England by the use of a molded lining containing no wire.

The use of lining in short segments with gaps between them has been advocated. This idea can be correlated with the theory of the cause of squeaking by the assumption that the attaching of the lining in segments permits greater flection of the band and therefore a greater area of surface contact, hence more complete damping of the vibration caused by abrading particles.

If the theory of the cause of squeaking is applied strictly, any squeak can be damped or muffled by moderate-pressure contact of the lining with the drum at 180 deg. from the particle that is plowing a furrow in the drum. Such particles are likely to be located in regions of highest pressure, which regions, on flexible external bands, will be near the adjusting-screws. The most successful adjustments, therefore, will be those that give good working-contact for about 5 in. on both sides of the anchor bracket. In this respect, practice accords fully with the theory.

OFFICERS OF THE SOCIETY

(Concluded from page 146)

its trip abroad during July, 1919, to make a study of foreign screw-thread practice. Together with Dr. Dickinson, of the Bureau of Standards, he visited Dr. Dixon of Manchester University and brought back to this Country a statement of the theory of engine-knock and detonation.

He proposed and aided in the movement to bring the automotive and petroleum industries together for the purpose of dealing promptly with the fuel question. Mr. Horning was chairman of the Committee on Utilization of Present Fuels in Present Engines, whose first report was presented at the 1920 Semi-Annual Meeting of the Society. He also proposed the plan of inviting the leading internal-combustion engineers of Europe to visit this Country to take part in meetings of the Society. Mr. Horning was elected First Vice-President at the 1921 Annual Meeting and served as President for the last administrative year. He has been a member of the Research Committee, being its chairman in 1924, and was active in initiating the Research Department. Mr. Horning was a member of the Committee on Standardization Policy for the year 1925.

A Suggested Remedy for Crankcase-Oil Dilution

By ROBERT E. WILSON[1] AND ROBERT E. WILKIN[2]

ANNUAL MEETING PAPER *Illustrated with* CHARTS

ABSTRACT

THE dilution of crankcase oils with the heavy ends of gasoline constitutes the outstanding present-day problem in the lubrication of automobile engines. This paper first presents the results of extensive tests designed to determine the rate and extent of dilution for various types of car under various operating-conditions. From these results it appears that, in the average car in winter service in the northern half of the Country, the viscosity of the original oil drops to about one-third of its original value in the first 150 to 180 miles of intermittent operation. Beyond this the viscosity, contrary to general opinion, remains fairly constant at an equilibrium value corresponding to about 15 per cent dilution, where, on the average, the rate at which fresh diluent enters the oil is practically balanced by the rate at which it is eliminated therefrom. Individual cars, of course, vary rather widely from this average figure, depending partly upon the design and condition of the car, but to a greater extent upon the operating conditions. Certain theoretical equations with empirical constants are shown to correspond closely to the observed curves giving the change in dilution with mileage.

With the average oil losing one-third of its viscosity in the first 150 miles of winter operation, to prescribe any ordinary type of oil which will have a really proper viscosity throughout any reasonable period of service is obviously impossible. In general, the widely used medium grades of oil, having around 325-sec. viscosity, are probably the best compromise available; but, for the first 50 miles of operation, their viscosity is considerably too high for easy starting when cold or for effective cold-lubrication in most cars. After 150 miles, the amount of dilution is, in general, so great as to reduce the viscosity to a point too low for safety, especially as road dust and grit accumulate. The use of a heavier oil accentuates the first set of difficulties and undoubtedly causes much of the scoring and wear of cylinders and rings, while the use of a much lighter oil gives an average viscosity after about 150 miles, which is far too low for safety.

As a remedy, this paper suggests the use of a fairly heavy oil, of from 500 to 575-sec. viscosity at 100 deg. fahr., blended with from 10 to 12 per cent of a distillate having a boiling range *substantially identical* with that found in the average crankcase oil at equilibrium. By this means it is possible to produce an oil with an initial viscosity around 220 sec., which, being thin enough, gives easy starting and good cold-lubrication and yet is so near the average equilibrium-dilution that, in general, it maintains a viscosity in this optimum range throughout its entire period of service. In warm weather, or in cars in which the average running-temperature is high, some of this diluent will shortly be driven-off to give a somewhat higher viscosity, which is desirable for such vehicles, while cars kept in cold garages and frequently started and stopped will have a somewhat lower equilibrium-viscosity, as is desirable for such vehicles.

These theoretical considerations have been fully confirmed by extensive comparative tests in two fleets of cars and trucks operated both summer and winter on the old and new types of oil. Changes in dilution and viscosity were followed closely, and the results for different types of car are presented graphically. If a car dilutes its oil to more than 20 or 25 per cent, the viscosity of even the new type of oil enters a range where the factor of safety is low but, in any case, the new oil is better than the old. If car builders can, by design and by education, keep dilution below 20 or 25 per cent, this oil should solve the remaining dilution problem in a very satisfactory manner. The factors and limitations that determine the optimum composition of the new type of oil are also discussed. Present specifications are, of course, not applicable to these oils.

WITHOUT question, the outstanding problem in the lubrication of automobile engines is the situation produced by the fact that the heavy ends of the motor fuel tend to accumulate in the crankcase oil and greatly reduce its viscosity, especially in winter operation. At most of the recent meetings of the Society, the session on lubrication has been devoted largely to a discussion of this problem and various possible solutions thereof. While much progress has been made in determining the effect of different factors on the dilution of the crankcase oil and some interesting appliances have been brought forward which should reduce dilution if installed on new cars, nothing has been suggested thus far which offers reasonable promise of reducing it markedly on existing cars or of eliminating it even on specially equipped new cars. This further study of the problem and a specific suggestion for its solution can, therefore, be offered without any need for apology.

It appears to be well recognized[3] that the two factors of most importance in producing dilution are cold starting with a choke, which introduces a considerable quantity of liquid gasoline into the cylinders and thence to the crankcase, and excessively cold cooling-water, which causes the heavy ends of gasoline to condense in the cold oil-films on the cylinder-walls and wash down into the crankcase. Air temperature, the use of hot-spot manifolds and the "blow-by" of vapors past loose rings seem to be much less important than has frequently been assumed.

Acting in the opposite direction are certain factors tending to eliminate this diluent from the oil. Again, the cooling-water temperature is important for, whenever it heats-up to a proper operating temperature, say to 160 deg. fahr., diluent is eliminated fairly rapidly from the film on the cylinder-walls, which is constantly being replaced by fresh oil from the crankcase. The

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[2] Engine laboratory, Standard Oil Co. of Indiana, Whiting, Ind.

[3] See THE JOURNAL, July, 1924, p. 69; Factors Affecting the Rate of Crankcase Dilution, by J. O. Eisinger.

See THE JOURNAL, July, 1925, p. 58; Cylinder and Engine Lubrication, by A. Ludlow Clayden.

crankcase-oil temperature is also important, especially if much "breathing" of air into and out of a crankcase occurs, as in the case of four-cylinder cars. Any blow-by of hot exhaust-gases undoubtedly would help to eliminate dilution by this route, especially if the crankcase oil were warm.

Theoretically, the rate of elimination by all these methods must be approximately in direct proportion to the quantity of diluent present in the oil, as the greater the quantity present is, the higher its vapor pressure or tendency to escape will be. As the net, or observed, rate of dilution is the difference between the true rate at which diluent enters the oil and the rate at which it is eliminated, the observed dilution would, on theoretical grounds, be expected to increase rapidly at first and then more slowly as the amount of diluent and, hence, the rate of elimination, increased. Eventually a point of equilibrium should be approached at which the rate of eliminating diluent would just balance the rate at which it comes in. Even then the amount of dilution would, of course, have temporary increases just after starting, and decreases after running hot for some time, but the average amount of diluent present should remain substantially constant under fairly uniform operating and weather conditions. That this is substantially true is indicated by experimental work mentioned later.

[4] See *Power*, Nov. 7, 1922, p. 720; Causes of Poor Cylinder-Lubrication in Internal-Combustion Engines, by W. F. Osborne.
See THE JOURNAL, July, 1924, p. 93; Engine Oil-Consumption and Dilution, by Neil MacCoull.
See *Automotive Industries*, July 31, 1924, p. 242; Scuffed Pistons Result from Cold Jacket and Lack of Oil, by Frank Jardine.
See THE JOURNAL, December, 1924, p. 488; Dilution Needed for Easy Starting.
See THE JOURNAL, May, 1925, p. 498; Automotive Research Report on Oil Dilution and Contamination.
See THE JOURNAL, December, 1925, p. 605; Engine Corrosion, Its Causes and Avoidance, by Frank Jardine.

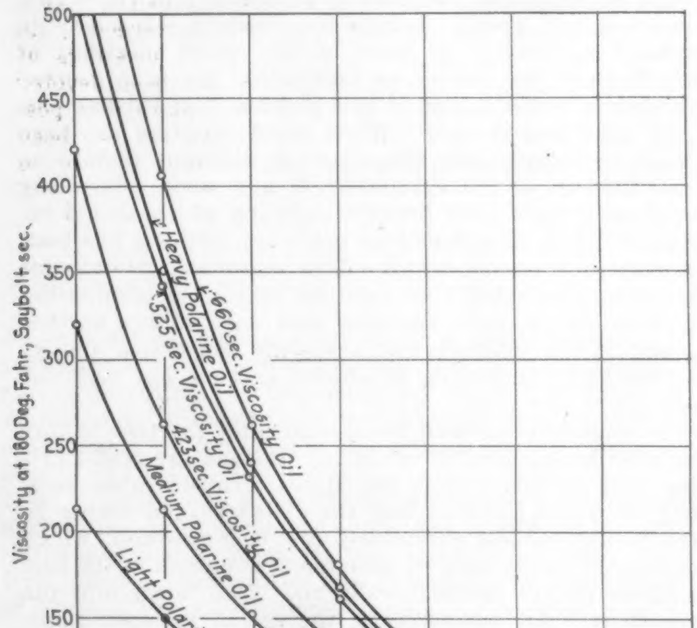

FIG. 1—DILUTION EFFECT ON SAYBOLT VISCOSITY
The Curves Show the Effect of Dilution on the Saybolt Viscosity of Polarine Oils

The very unsatisfactory nature of the present situation in automobile lubrication from both an engineering and a practical standpoint is illustrated best by what happens in the case of the oil in the average car in winter service in the northern half of the Country, as indicated by several recent surveys discussed in detail later. This average car starts with fresh medium-grade oil, the viscosity of which is about 325 Saybolt sec. at 100 deg. fahr. Regardless of the pour-test of the oil, this viscosity is undoubtedly too high for easy starting in a cold garage, or for proper circulation in the average oil-pumping system until the engine has warmed-up. Evidence is accumulating that the damage done to pistons and to cylinder-walls during this warming-up period with fresh oil is both frequent and serious.[4] After running about 180 miles, however, the oil in this average car has become diluted about 15 per cent under winter conditions, and its viscosity has dropped to about one-third of its original value. The average automotive or lubricating engineer would unhesitatingly declare that this is too low a viscosity for satisfactory lubrication, but the fact must not be lost sight of that the typical car under average winter-conditions does operate, with reasonably satisfactory results, provided the oil is changed about every 500 miles to prevent the accumulation of excessive quantities of road dust and grit and in spite of the fact that its viscosity for the last 300 miles averages around 115 Saybolt sec. Furthermore, engines have been operated satisfactorily in block-tests for several hundred hours with oils of even lower viscosity, provided care is taken to prevent the admission of dust or grit with the intake air.

On the other hand, it must be admitted that viscosities around 115 Saybolt sec. represent a very small factor of safety above a real danger-point, and that cars which dilute somewhat more than the average or which happen to accumulate an excessive quantity of dirt before the oil is changed, are very likely to acquire scored cylinder-walls or badly worn bearings and to bring discredit on both the automobile builder and the oil refiner. Thus, an oil of 325-sec. initial-viscosity, when diluted 20 per cent, as happens in many cars, has a viscosity of only about 87 sec., about one-fourth of its initial viscosity, and is certainly in an unsafe region. Dilution-viscosity curves for the various grades of automobile oils marketed by our company are shown in Fig. 1.

It is thus seen that the average present-day car is using an oil which is at best a compromise, being too viscous at the start for satisfactory winter lubrication and too thin after about 200 miles of operation. Almost every engineering staff of the larger oil and automobile companies has some members who focus their attention on dilution and demand an oil of higher initial-viscosity, and other members who focus their attention on the problems of cold starting and cold lubrication who insist that the initial viscosity of the oil should be lower. The general result has been that, in the case of the higher priced cars, which generally dilute the worst, the compromise is in the direction of using an oil heavier than the average, while in the case of the cheaper cars, which are more often kept in unheated garages and are more prone to have cold-weather starting-difficulties, the compromise has been in the direction of recommending lighter oils. While these compromises are probably the best that can be made for average conditions for given models, they certainly do not represent really satisfactory solutions of the problem. Thus, those who lean toward the use of a heavier oil to counteract dilution find that, to get an oil with a viscosity as high as 110

sec. when 20 per cent diluted requires an initial viscosity around 500 sec., which is very undesirable for cold starting and lubrication; whereas, on the other hand, those who prefer an oil of around 220-sec. initial-viscosity that will give easy starting and good cold-lubrication find that this oil on diluting only 15 per cent has a viscosity around 70 sec.

These factors show clearly the difficulty of designing the lubricating systems of automobiles properly. The absurdity, in preparing specifications and the like, of haggling over matters of 20 or 30 sec. in initial viscosity is also apparent, when only 1-per cent dilution drops the viscosity this much, and the variation in the operating dilution between two different cars of the same make is frequently 10 or 15 per cent. While it may shatter some illusions that have been more or less fostered by

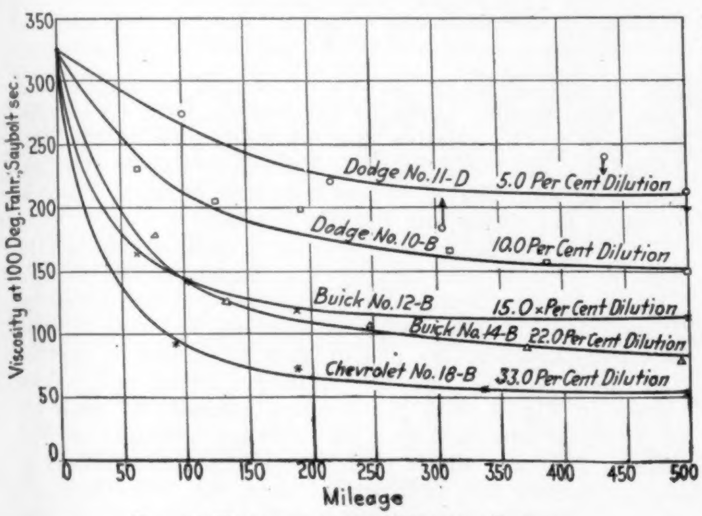

Fig. 2—Viscosity versus Mileage Curves
The Data Were Obtained under Winter Conditions Using Medium Polarine Oil

both the oil and the automotive industries, it is nevertheless true that the specification of oil viscosities for given cars is not an exact science but represents an unsatisfactory compromise between the demands for easy starting and good cold-lubrication with fresh oil on the one hand and fairly good viscosity after 15 or 20-per cent dilution on the other. When lubrication troubles do occur the difficulty is to tell whether they are due to too heavy or too light an oil, because the same general type of injury to a given engine from a given grade of oil may result either from no lubrication for 5 to 10 min. after starting with the cold fresh-oil, or from operating a hot engine with the same oil excessively thinned-out by dilution. It should be noted in this connection that the real reason for recommending changing of the oil after 500 miles is not that the viscosity or the dilution is changing much at this time, but that dirt is accumulating to a dangerous extent if the oil is of low viscosity.

To discuss further the present unsatisfactory and illogical "state of the art" in the selection of automotive lubricants is probably unnecessary. It is all fundamentally due to the three or the four-fold change in the viscosity of lubricants under typical winter-conditions.

To make the bearing of the subsequent sections of this report clearer to the reader, let us assume that the above mentioned equilibrium-dilution figure for a given car under winter operating-conditions is 15 per cent, at

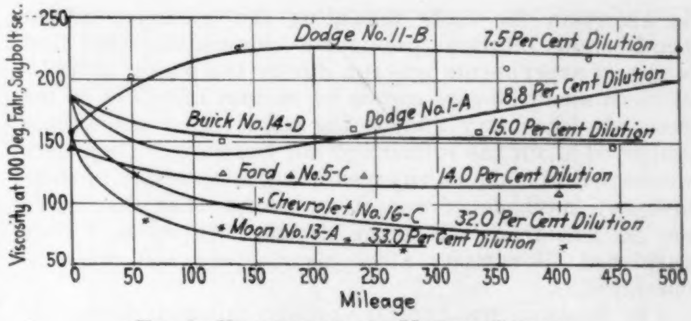

Fig. 3—Viscosity versus Mileage Curves
The Data Were Obtained under Winter Conditions Using "Non-Diluting" Oil

which point the rate of elimination of diluent from the oil just equals, on the average, the rate at which diluent comes in from the engine. It should be possible to make an almost ideal lubricant for such an engine by blending a rather heavy oil with 15 per cent of light material identical in boiling range with that actually found in the crankcase oil at equilibrium, choosing the viscosity of the heavy oil to give the blend a satisfactory operating viscosity of say 160 sec. at 100 deg. fahr. Such a blend should maintain a substantially constant and entirely satisfactory viscosity in this particular car, giving far easier starting and better cold-lubrication than an ordinary light oil when fresh, and yet as good viscosity after several hundred miles of running as if the crankcase had been filled originally with an oil of 525-sec. viscosity! With such a "non-diluting" oil[5] available, the proper design of a 100-per cent reliable lubrication-system would be a comparatively simple matter. Whether or not such a solution of the problem would be entirely practicable for general use obviously depends upon the answer to the following questions:

(1) Does dilution actually approach an equilibrium in a given car under given operating conditions?
(2) If so, about how soon is such an equilibrium substantially reached?
(3) What is the magnitude of this equilibrium dilution for different cars under different operating-conditions?
(4) What is the composition of this diluent and how much does it vary?
(5) Is it possible to get a single blended-oil of this "non-diluting" type that will give satisfactory results in practically all cars?

The succeeding sections of this paper are devoted to answering these questions, in order.

Data on Rate of Change of Dilution with Mileage

To determine the rate of change of dilution with mileage under ordinary conditions of winter service and

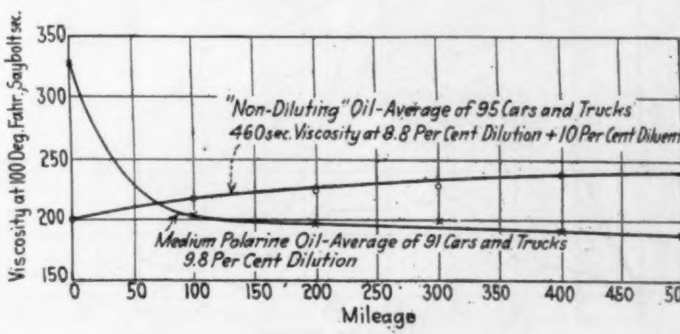

Fig. 4—Viscosity versus Mileage Curves
Average Viscosity of Medium Polarine and of "Non-Diluting" Oil at 100-Mile Intervals and the Average Dilution at 500 Miles under Summer Conditions Are Shown

[5] This term "non-diluting" is used for convenience throughout the paper, the quotation marks indicating that it is not held out to be a strictly accurate description when the oil is used in cars that dilute much more than the average.

to ascertain the facts regarding the existence of the equilibrium dilution previously postulated, the first series of experiments was run during the winter of 1924-1925 on about 25 cars owned by various members of the research laboratory and of the sales school and others employed about the refinery of our company. They were instructed to make no changes in adjustments or in their ordinary methods of operation, except that they were not to add fresh oil before driving 500 miles. They furnished oil samples after about every 100 miles of operation.

Fig. 2 shows five typical viscosity-mileage curves obtained on crankcase-oil samples from cars filled with Medium Polarine, and Fig. 3 illustrates similar results from cars filled with the "non-diluting" type of oil containing 10 or 12 per cent of diluent in a fairly heavy-base oil. For reference purposes, the percentage of dilution corresponding to the last point on each curve is shown thereon.

These two sets of curves bring out clearly the fact that, although individual points deviate considerably from the curve, due to fluctuations in outside temperature and in the frequency of stopping and starting, in general, 90 per cent of the change in viscosity takes place in the first 150 to 180 miles. Beyond this mileage the viscosity curve flattens off to have practically an equilibrium value. The one exception to this was Dodge No. 1A, Fig. 3, which was typical of three or four cars in which the average outside-temperature increased considerably before the 500-mile test was completed. As a result, the dilution increased at first and then decreased with the coming of warmer weather. This is, of course, just another demonstration of the equilibrium principle, except that here the true "equilibrium dilution" changed during the test and diluent was for a time eliminated more rapidly than it came in.

In a number of cases two successive 500-mile runs were made on the same car, in which one run was started with the "non-diluting" type of oil and the other with Medium Polarine. In all cases the equilibrium dilution observed was of the same order of magnitude, although differences in weather conditions over the two periods naturally prevented exact correspondence. Two such comparative results are shown in Figs. 2 and 3 on Dodge

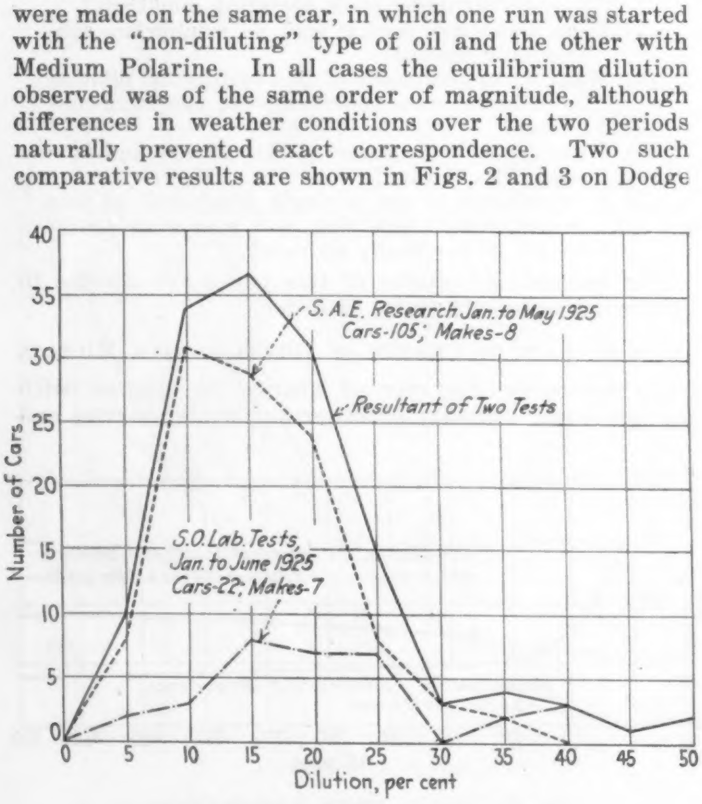

FIG. 5—NUMBER OF CARS VERSUS DILUTION CURVES
The Data Were Obtained under Winter Conditions for a Total of 140 Cars and a Distance Greater Than 400 Miles

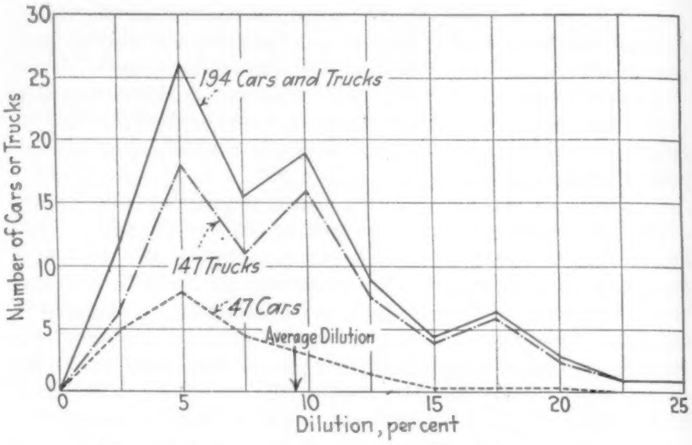

FIG. 6—NUMBER OF CARS VERSUS DILUTION CURVES
The Data Were Obtained under Summer Conditions for a Distance of 500 Miles

No. 11 and on Buick No. 14. It should be emphasized that these results, taken by themselves, have no significance as to the relative diluting-tendencies of the different makes of car, as wide differences due to varying length of run, heated versus unheated garages, method of using the choke, and the like existed.

To study the behavior of this oil in summer, the entire fleet of trucks and cars of the Standard Oil Co. in Chicago and in Detroit were operated for 500 miles on "non-diluting" oil and then on Medium Polarine. Samples were taken at the end of each 100 miles of service and the viscosity and the dilution determined. The curves in Fig. 4 show the average viscosity of each oil at 100-mile intervals and the average dilution at 500 miles. This test shows that the equilibrium dilution is less in summer but, as in winter tests, the "non-diluting" oil has a higher viscosity after 100 miles of service and the change of viscosity from start to finish is very small as compared to that for Medium Polarine. The equilibrium dilution is about the same for both oils, as demanded by the theory.

THE MAGNITUDE OF THE EQUILIBRIUM DILUTION FOR VARIOUS CARS

While the results obtained at our company's laboratory last winter, typified by the curves in Figs. 2 and 3, are adequate to show the existence of the equilibrium dilution and the fact that most of the change takes place in the first 150 to 180 miles, they are not adequate to indicate the relative number of cars that, under normal winter-driving conditions, will dilute to given percentages of diluent. To secure such results, some data obtained by the Society's Research Committee and the data taken at our laboratory were analyzed. Fig. 5 shows the Society's results from 105 cars taken at various places in the United States during the latter part of the winter, and those from 35 test-runs made by our laboratory. Cars that had not been run for at least 400 miles before the end of the test were not considered, lest in some of these cases substantial equilibrium had not been reached.

To present the results graphically, all the cars showing equilibrium dilutions within $2\frac{1}{2}$ per cent on either side of each even 5-per cent point were plotted against that point. The upper full-line shows the sum of all the tests and indicates fairly clearly that the average winter equilibrium-dilution is about 15 per cent and that about 90 per cent of all cars lie between the limits of 5 and 25 per cent. It seems probable that those relatively few cars which dilute more than 25 per cent have rather serious defects in construction, adjustment or method of

operation which would need to be looked after to get satisfactory winter-lubrication with any reasonable kind of oil.

The results of the summer test made by our sales department were analyzed similarly and are represented graphically in Fig. 6. The cars and trucks were grouped for intervals of $2\frac{1}{2}$-per cent dilution instead of 5 per cent. The full line shows the sum of both cars and trucks. The average dilution for both cars and trucks in this summer test was 9.4 per cent. It is evident, however, that many cars in summer will operate at around 5-per cent dilution. Rather strangely, the trucks showed greater average dilution than the cars. This may be due to the fact that most of these cars were Fords.

Composition of the Diluent

As pointed out in the introduction to this report, if a prepared mixture of heavy oil and diluent is to maintain substantial equilibrum in service, it is vital that the boiling range of the artificial diluent be *substantially identical* with that of the equilibrium solution that naturally would be formed. If it were much heavier, as, for example, if the heavy end of kerosene were used, it does not in general evaporate at a rate sufficient to balance the rate at which diluent comes in and equilibrium is not reached until nearly as much diluent has been added as if the original oil had not been blended. This additional dilution, of course, lowers the viscosity well below a safe operating-limit.[6] If, on the other hand, the artificial diluent used were much lighter than the natural diluent, it would evaporate too rapidly and give an oil too heavy for the best results between the time that most of the light artificial-diluent disappeared and the equilibrium amount of natural diluent was picked-up.

In view of this fact, it was important to determine the composition of the diluent that was naturally produced in the operation of cars, and to see whether it varied much with conditions. The diluent was removed from used crankcase oils by fractional distillation and the boiling range thereof was determined by an Engler distillation. Samples of diluent were recovered from a large number of used crankcase oils that contained from 9 to 36-per cent dilution. These oils were used under a variety of winter conditions and in a large number of cars. The composition of the diluent in each case was practically the same and the average boiling-point of each was almost exactly the same as that of a large composite-sample. Fig. 7 shows the Engler distillation of the composite-sample. A special heavy-naphtha was prepared which corresponded very closely to this boiling range and was used in making up the "non-diluting" oils and the dilution-viscosity curves.

The Selection of a Satisfactory "Non-Diluting" Oil

From the foregoing it is apparent that no single "non-diluting" oil can maintain a constant viscosity in service in more than a limited number of cars, but that the general principle can be employed to prevent excessive fluctuations of viscosity in any ordinary car, and to give better lubrication at all times than that afforded by any of the ordinary types of oil. The following discussion is designed to show how the various factors influence the selection of the best composition for a "non-diluting" oil on the basis of the varying service conditions it should meet. The method employed is indicated in Fig. 8, which represents all "non-diluting" oils that might reasonably be considered and the relatively small area that we consider best.

[6] The heavy end of kerosene can, however, be used as the diluent for a very heavy oil to be used in a kerosene-burning engine, with similarly desirable results.

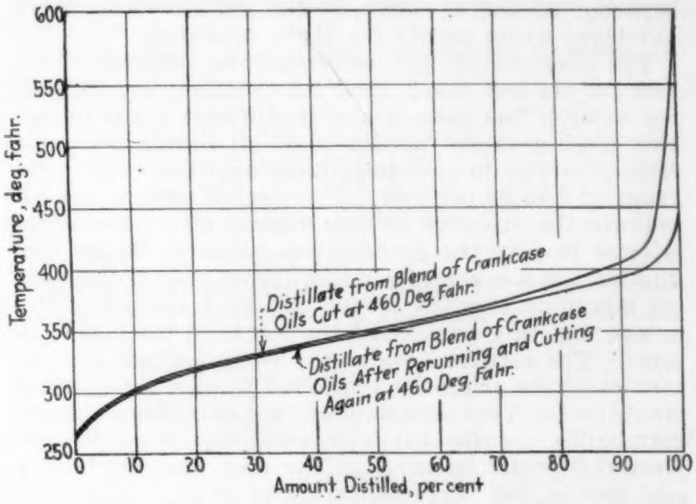

Fig. 7—Engler-Distillation Curves
These Show the Results of Distilling a Composite Sample of Diluents Recovered from a Large Number of Used Crankcase Oils, These Having Been in Service in a Large Number of Cars under a Variety of Winter Conditions

In Fig. 8, the abscissas represent the original viscosity of the oil before adding any diluent and the ordinates represent the percentage of dilution. The curved lines represent the viscosity of the blends thus produced. For instance, an oil of 215-sec. viscosity, shown by the third curve from the top, evidently can be made either from an oil of 215-sec. viscosity with 0.0 per cent of diluent, an oil of 400-sec. original-viscosity with 7.4 per cent of diluent or an oil of 500-sec. viscosity with 10.0 per cent of diluent; and many intermediate possibilities exist.

In selecting a satisfactory oil the first requirement, to assure easy starting in winter and good cold-lubrication, is that the initial viscosity shall not be greater than about 240-sec. at 100 deg. fahr. or not much above that of Light Polarine. The lower limit for the initial viscosity was set at 190 sec., largely to avoid excessive sales-resistance from motorists who would not believe a lighter oil could possibly lubricate properly. The selection of these limits gives the curved cross-hatched band

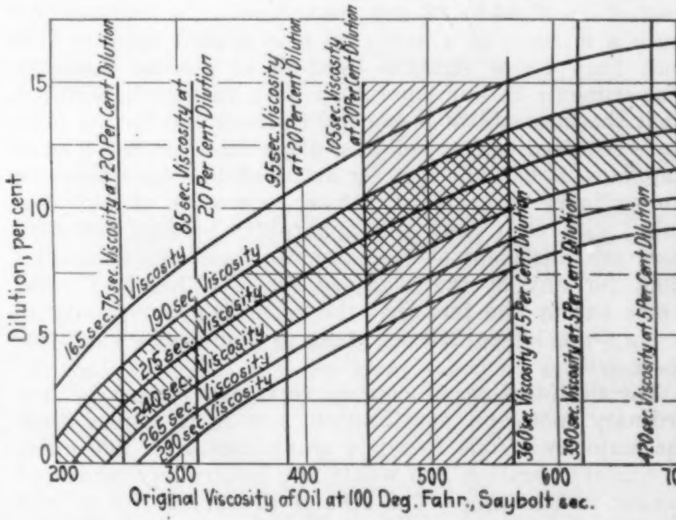

Fig. 8—"Non-Diluting"-Oil Composition
The Basis for Selecting the Best Composition for an Oil of This Designation That Will Meet Varied Service Conditions Is Presented Graphically

between 190 and 240-sec. viscosity, within which limits any blend would satisfy the above conditions.

The other limits that determine the selection of the best oil are not based upon its condition as marketed but after it has been in use in different kinds of service, since a single "non-diluting" oil should give satisfactory service in cars that dilute anywhere within the range of 5 to 20 per cent. The vertical lines at the left indicate the viscosity of the original oil that must be selected to give the specified viscosities at 20-per cent dilution. It was considered that the oil used should have the minimum viscosity of 105 sec. when diluted to this extent, and this established the left-hand limit as indicated. The vertical lines at the right indicate the viscosities of the original oil required to give the specified viscosities at 5-per cent dilution, and here the maximum permissible viscosity has been tentatively set at 360 sec. Even this would be too high for easy starting from a cold garage, but very few cars kept in cold garages in winter would ever drive-out diluent until only 5 per cent is left. This established the fourth limit and left the area between the two vertical lines, 105-sec. viscosity at 20-per cent dilution and 360-sec. viscosity at 5-per cent dilution, as that which satisfied the last two conditions. The small, doubly cross-hatched area where the two bands cross represent oils, that will fulfill all the prescribed conditions as discussed.

We would especially welcome a discussion of these limits and of the best composition for an oil of this type. Oils from both extremes of the preferred area have been used extensively with entire success. Most of the tests reported in this paper were made with an oil near the left-hand limit, 460-sec.-viscosity oil with 10 per cent of diluent, but our present opinion is that the viscosity and the percentage of diluent should both be higher, say 525-sec.-viscosity oil with 11 per cent of diluent, which would be near the center of the preferred area. Such an oil has the rather striking properties stated in Table 1.

TABLE 1—PROPERTIES OF 525-SEC.-VISCOSITY OIL WITH 11 PER CENT OF DILUENT

Viscosity at 100 Deg. Fahr., Saybolt sec.	215 to 220
Flash-Point, deg. fahr.	170 to 180
Pour-Test, Depending upon the Type of Oil Used, deg. fahr.	0 to 20
Viscosity When Diluted 15 Per Cent, Saybolt sec.	162

While 11-per cent dilution generally lowers the pour-test of an oil 10 or 12 deg., to secure a low pour-test for such a mixture of a heavy oil plus diluent is more difficult than for a straight light-oil of similar viscosity. Experiments in our laboratory have indicated, however, that the viscosity at 0 deg. fahr., measured by the pressure required to force oil at a given rate through a small capillary, is actually less for an oil of this type than for an ordinary light-oil of 215-sec. viscosity at 100 deg. fahr. with zero pour-test, apparently because the temperature coefficient of viscosity for these oils is smaller than for any of the ordinary types. This is further borne out by the fact that the reduction in viscosity in going from 100 to 210 deg. fahr. is abnormally small for these oils.

The flash-test is, of course, very low, judged by any ordinary motor-oil specification, but it is higher than the majority of oils found in crankcases after 200 miles of winter operation and would not involve any source of danger in handling. The cost of producing the oil will be slightly higher than for the present medium-oils, the extra cost of the heavier oils being only partly counterbalanced by the use of the 11-per cent diluent.

PERFORMANCE OF THE RECOMMENDED OIL IN SERVICE

The previously discussed curves in Fig. 3 have shown just what took place in six typical cases where a comparatively low-viscosity "non-diluting" oil was used in cars at Whiting, Ind. These curves are representative of the results obtained in more than 20 cars operated on this oil during most of the winter of 1924-25. The owners of these cars all reported easy starting and no lubricating difficulties, although a few of the cars diluted beyond what would be considered a desirable limit.

The question was also raised as to the suitability of these oils for summer use. As pointed out previously, the equilibrium dilution in a given car in summer is considerably less than that in winter, so that in this case it would be expected that the "non-diluting" oil would lose some diluent during the first 100 miles and give a moderately high operating-viscosity, as would be desired. Here, again, the results were uniformly favorable on all types of car and truck, absolutely no lubrication troubles of any kind being experienced. The average viscosity at the end of 500 miles of service was much higher than when Medium Polarine was used in the same 91 cars and trucks. Careful records were kept of oil-consumption, and the average quantity of oil used was practically identical with that for Medium Polarine.

A somewhat heavier "non-diluting" oil, such as that described in the last section, is again being used in the company's cars and trucks; but, in this case, part of the comparison is being made against Heavy Polarine. The results with the "non-diluting" oil have again been entirely satisfactory, though final comparative results are not yet available.

Since the "non-diluting" oil is characterized by having a much lower initial-viscosity than Medium Polarine and yet considerably higher viscosity after running about 200 miles, the question naturally arises as to where the two viscosity-curves will cross under service conditions. The results of comparative tests under similar conditions have indicated that this generally takes place at between 60 and 100 miles if the operating conditions are similar for the two tests. In this connection it seemed of some interest to work out the theoretical equation for the net rate of dilution of both ordinary and "non-diluting" oils, determining the necessary constants from experimental data, to see how well the resulting calculated curves check with those observed.

As indicated previously, for a given car operating under fixed conditions, the rate at which gasoline enters the crankcase should, over any considerable period, be substantially constant, although it would fluctuate from mile to mile as the engine warms-up. On the other hand, the rate at which diluent is eliminated from the crankcase should be proportional to the vapor pressure of the diluent in the crankcase oil which is, in turn, approximately proportional to the percentage of dilution. The difference between these two rates would then be the net rate of dilution, the quantity actually observed in making tests. If, then, x represents the percentage of dilution and m the miles traveled, dx/dm represents the net rate of dilution, and should equal $K - K_1x$ where K is the constant for the rate of diluent addition and K_1 that for the rate of elimination. These terms are true constants for any given car operating under fixed conditions. The fundamental equation is therefore

$$\frac{dx}{dm} = K - K_1x \qquad (1)$$

which is most readily integrated when written as

$$m = \int \frac{dx}{K - K_1x} \qquad (2)$$

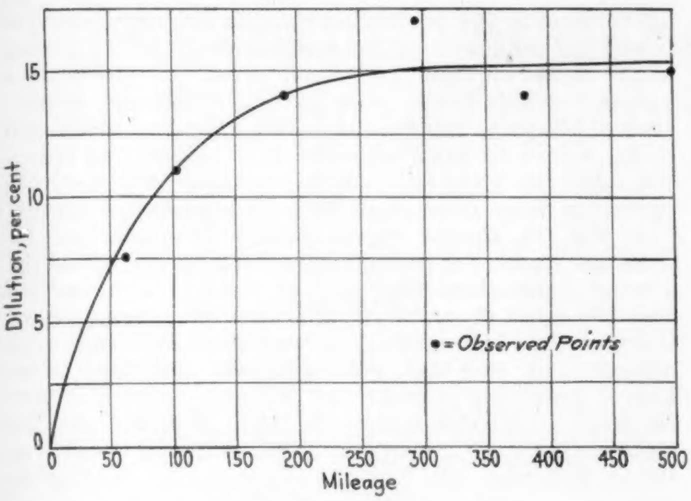

FIG. 9—RATE OF DILUTION
The Curve Shows Theoretical versus Actual Results. Values Taken for the Theoretical Curve are: $X_e = 15.4$; $K_1 = 0.0126$; and $K = 0.194$. The Observed Points, Which Were Obtained from Buick No. 12-B, Are Fairly Typical. The Chart Illustrates the Agreement Between the Observed Dilution and the Theoretical Curve

When equilibrium is reached, the net rate of dilution becomes zero owing to the fact that the rate of elimination is then exactly equal to the rate of diluent addition. This fact can be represented by

$$\frac{dx}{dm} = K - K_1X_e = 0 \tag{3}$$

whence

$$K = K_1X_e$$

or

$$X_e = K/K_1 \tag{4}$$

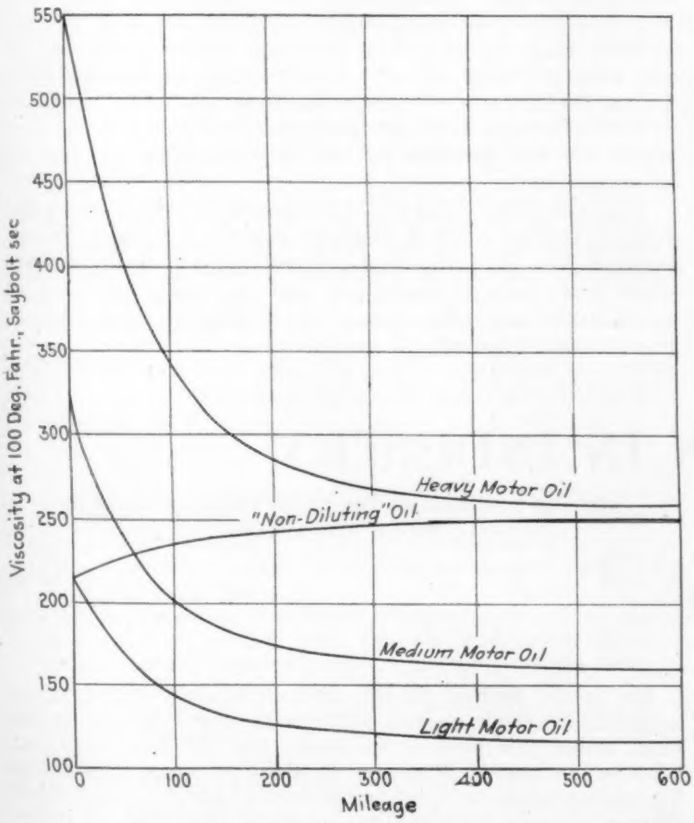

FIG. 10—VISCOSITY VERSUS MILEAGE CURVES FOR SUMMER OPERATION
The Calculations Are Based on Equation (12) and a Value of 0.01 for K_1. The Equilibrium Dilution, X_e, Is 9 Per Cent. The "Non-Diluting" Oil Is of 525-Sec. Viscosity and Has 11 Per Cent of Diluent

where X_e equals the concentration of diluent at equilibrium.

By the substitution of this value for K, equation (2) becomes

$$m = \int \frac{dx}{K_1X_e - K_1x}$$
$$= (1/K_1)\int \frac{dx}{X_e - x} \tag{5}$$

which integrates directly and becomes

$$m = -(1/K_1)\,[\log_e (X_e - x)] + C \tag{6}$$

The constant of integration, C, can be evaluated readily as, when m equals zero, x also must be zero. Therefore,

$$C = (1/K_1) \log_e X_e \tag{7}$$

and

$$m = (1/K_1) \log_e [(X_e - x)/X_e] \tag{8}$$
$$= -(2.3/K_1) \log_{10} [(X_e - x)/X_e] \tag{9}$$

which gives the dilution at any desired mileage for the particular conditions represented by K and K_1. The constant K can be calculated readily from equation (4), once K_1 and X_e are known.

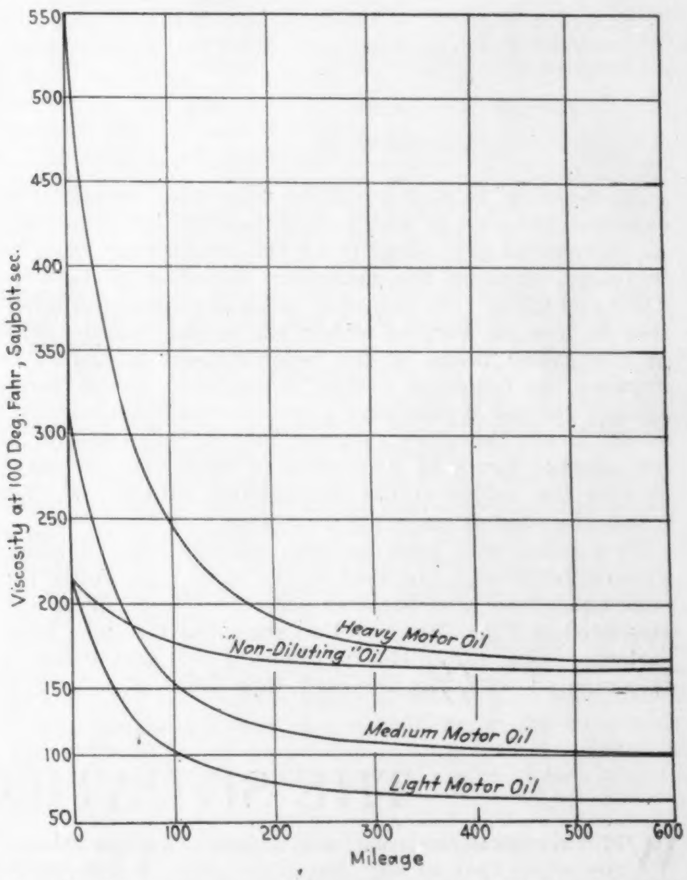

FIG. 11—VISCOSITY VERSUS MILEAGE CURVES FOR WINTER OPERATION
The Calculations Are Based on Equation (12) and a Value of 0.01 for K_1. The Equilibrium Dilution, X_e, Is 15 Per Cent. The "Non-Diluting" Oil Is of 525-Sec. Viscosity and Has 11 Per Cent of Diluent

In the event that the oil is diluted before being placed in the crankcase, x is no longer zero at zero mileage. The constant of integration, C, of equation (6) then becomes

$$C = -(1/K_1) \log_e (X_eX_p) \tag{10}$$

where X_p represents the percentage of original dilution. Substitution of this value in equation (6) gives

$$m = -(1/K_1) \log_e [(X_e - x)/(X_e - X_p)] \tag{11}$$
$$= -(2.3/K_1) \log_{10} [(X_e - x)/(X_e - X_p)] \tag{12}$$

This gives an integrated equation with two unknown quantities connecting dilution and mileage. By drawing a smooth curve through the observed points on the dilution-mileage curve for any car, it is possible to determine the two constants and then to plot the theoretical curve to compare with the actual one. By selecting the points of reference at 60 and 180 miles, the solution of the equation is fairly simple and the resulting calculated curves, in general, correspond well with those observed. Fig. 9 shows the agreement between the observed dilution and the theoretical curve for Buick No. 12-B, which is fairly typical. Table 2 shows the values calculated for K, K_1 and X_e from the curves shown in Figs. 2 and 3.

TABLE 2—CALCULATED VALUES FOR K AND K_1

Car	K	K_1	X_e, Per Cent
Dodge 11-B[7]	0.108	0.0159	6.8
Dodge 10-B	0.060	0.0050	12.0
Buick 14-D[7]	0.178	0.0127	14.0
Ford 5-C[7]	0.168	0.0115	14.6
Buick 12-B	0.194	0.0126	15.4
Buick 14-B	0.143	0.0066	21.3
Chevrolet 16-C[7]	0.263	0.0102	25.9
Chevrolet 18-B	0.317	0.0099	32.4
Moon 13-A[7]	0.314	0.0086	36.6
Average	0.195	0.0103	

[7] Cars using "non-diluting" oil.

In studying Table 2 it will be noted that, as might be expected, the rate at which diluent enters the crankcase, K, increases fairly steadily as the equilibrium dilution increases, showing the maximum variation as between 0.060 and 0.317. On the other hand, the rate of elimination K_1 does not vary so widely nor so consistently, most of the values being in the neighborhood of 0.01. In drawing the following curves to represent the performance of various typical cars starting with different kinds of oil, it was therefore assumed that K_1 was constant at the average figure of 0.01, while K varied as necessary to give the values of the equilibrium dilution, X_e, for which the various curves were drawn.

To predict with good accuracy exactly what happens when different oils are used in the same cars under the same conditions thus becomes possible. Such curves are presented in Figs. 10 and 11 to show the viscosity comparisons using either Heavy, Medium or Light Polarine as compared with the proposed "non-diluting" oil. Fig. 10 represents the performance under average summer-conditions with an average equilibrium-dilution of 9 per cent. It shows that the "non-diluting" oil starts at a viscosity which is the same as Light Polarine, crosses that of Medium Polarine oil at 60 miles and, after 200 miles, maintains practically the same viscosity as Heavy Polarine. It is the only oil that remains in a desirable operating-range throughout its normal period of service.

In Fig. 11, similar curves leading to similar conclusions are shown for average winter-conditions where the average equilibrium-dilution is 15 per cent. During the first 100 miles of operation, the high initial-viscosity of Heavy or of Medium Polarine makes cold starting very difficult and does not give adequate cold-lubrication. Fig. 11 shows that, for the first 100 miles, "non-diluting" oil gives all the advantages of Light Polarine and for the remainder of its service is practically the same as Heavy Polarine. It would, of course, be possible to prepare a special "non-diluting" oil for those few cars that dilute very badly, making it up from much heavier oils plus from 20 to 25 per cent of diluent; but, for various reasons, this does not appear to be a very satisfactory solution of the problem. To solve the problem of lubrication in such cars, some improvement should be made in their mechanical construction, their adjustment or their method of operation to bring them into the range of dilution found in most other cars. Most of the so-called dilution-eliminators are applied to cars of the type that tends to dilute severely and to keep the dilution down to around 10 per cent, and cars thus equipped are therefore ideal subjects for lubrication with the recommended "non-diluting" oil. In any case it is clear that for the great majority of cars, the recommended "non-diluting" oil is very much better than ordinary types of automobile lubricant; and that, even for extreme conditions, where it might not give perfect results, it is in any case distinctly better than any of the present types of oil. In the light of all the foregoing facts, our laboratory believes that the proposed type of oil represents the most practical solution yet proposed for the problem of crankcase-oil dilution and its attendant evils.

In conclusion, we desire to acknowledge the very helpful cooperation of H. J. Saladin and V. C. Parker, of our company, in planning and supervising the sales-department tests herein described, and for their advice and suggestions in determining the optimum composition for the new type of oil.

THE SITUATION IN INDUSTRY

WITH regard to the situation in industry, a better balance now exists than at any time since 1920. A few industries are still in a depressed condition, but they are steadily showing signs of improvement. Some of the industries that were in the doldrums 2 years ago now seem to be fully recovered. However, the significant fact remains that industry still has a large excess of productive capacity that cannot be utilized until consumer buying power has substantially increased.

The greatest change of all has taken place in the relation between farm and factory. The rise in the prices of farm products, particularly during the past year, has put the purchasing power of the farmers' product within striking distance of its pre-war parity. According to data prepared by the United States Bureau of Agricultural Economics, the relative purchasing power of the farmers' product at wholesale for each of the years 1920 to 1925 compares with pre-war years as follows:

AVERAGE PURCHASING POWER OF FARMERS' PRODUCT
1910-1914 PRICES BEING TAKEN AS 100

1920	85
1921	69
1922	74
1923	79
1924	83
1925 (July)	91

The above figures do not, of course, offer the slightest suggestion that the farmer will venture forth on a spending orgy, either this year or the next. He still has debts that must be liquidated. Moreover, it might be many years before his buying power returned to the level of pre-war days, when farm prosperity was relatively greater than that of industry. It is noteworthy, however, that the steady improvement in the farmer's position is gradually removing one of the factors that have stood in the way of inflation.—G. E. Putnam in *American Bankers Association Journal.*

The Nature and Sources of Pigments Used in Automobile Coloring

By CHARLES A. GREENE[1]

ANNUAL MEETING PAPER

ABSTRACT

COLOR pigments for use in automobile finishes must be (*a*) permanent, so that they will not fade in sunlight; (*b*) insoluble in varnish or lacquer, so that they will not bleed; (*c*) opaque, so that they will produce a solid covering-coat; (*d*) brilliant, to produce a pleasing luster; (*e*) light in weight, so that they will not settle in the liquid enamels and (*f*) soft in texture, and therefore easily ground in varnish or lacquer.

All pigments are divided roughly into three classes: inorganic pigments, derived from mineral or metallic sources; organic pigments, derived from living organisms or from coal-tar products, and pigments made by a mixture of the two types, as by the precipitation of organic dyes upon metallic salts.

Certain types of colors were used before the days of Tut-ankh-amen and have not been improved upon for centuries, either economically or chemically. Other colors, however, are now made synthetically. Organic colors, originally derived from plants or insects, are rapidly falling into disuse because of lack of permanency. Some plant extracts precipitate on certain metallic or mineral bases and form permanent colors, and hence are still in extensive use although the same colors are now made artificially.

Because of the density of organic pigments having a mineral or metallic base, the color industry developed an organic pigment with an organic base. This is a yellow solution of para-nitro-aniline precipitated upon a beta-naphthol base and is so light that it will not settle out of the water solution. We now have purely organic yellow, red and maroon, and a green made from the yellow by the addition of a small percentage of Chinese blue.

The most brilliant permanent blue pigment becomes chemically active when ground in varnish or lacquer and soon destroys the carrier, hence the manufacturer of colored lacquers is forced to use the less brilliant but more permanent iron blues.

To obtain just as permanent maroon lacquer finishes as any maroon varnishes ever used is possible. They are developed from alizarine madder lakes and no difficulty is experienced in supplying any shade between wide extremes.

All white pigments are derived from mineral or synthetic metallic sources and are used as opaque body-pigments or as transparent base-extenders. Most black pigments, on the other hand, are of organic origin, some being obtained by calcining animal bones or ivory chips and others by the incomplete combustion of hydrocarbon oils and gases.

Manufacturers of cellulose lacquers have an extensive choice of colors that can be used successfully. These include bright red, Bordeaux maroon, wine color, chrome yellows from light lemon to deep orange, all shades of chrome green, Chinese or Prussian blue, and alizarine purple.

THIS subject should be approached from a practical technical point of view, therefore this paper will concern color only in its most concrete form and will avoid as much as possible anything relating to the artistic or theoretical. For instance, to what school we belong and whether we claim that red, blue and yellow are the three primary colors or hold that orange, green and violet are the only pure color sensations does not matter. What we are interested in is the actual material substances that we know as colored pigments, their nature, their source and why they are used in automobile finishes.

A colored pigment, to most of us, means simply a powder that produces, by reflecting and refracting light, what is known as a color sensation on the optic nerves. We rarely stop to consider how many qualities an ideal colored pigment should possess. It must be (*a*) fast to light, or permanent; (*b*) non-bleeding, or insoluble; (*c*) a solid covering, or opaque; (*d*) brilliant, or of clean tone; (*e*) light in gravity, fluffy and non-settling in enamels, and (*f*) soft in texture, or easily ground.

The quality of permanency, or fastness to light, is recognized by all. For instance, of two reds of about the same color, brilliancy and covering power, one fades badly upon exposure to light and the other stands up well.

The insolubility of one green powder is shown by dropping it into an oil, while another green powder is readily soluble and its use as a pigment would be impracticable.

Opacity is shown comparatively by two panels, one having a chrome yellow over a solid color in one coat, and the other what is known as a yellow lake, which has practically no hiding power or opacity.

The color palette of the ancients had, for permanent reds, practically an iron oxide like Venetian red and a madder lake. These two reds as used in those days, compared with two modern reds, show readily the value of brilliancy, which should be possessed by any high-grade pigment.

Gravity, or density, is important, especially in these days of thin spraying-lacquers. This property determines often how long a pigment will stay in suspension.

Texture, or softness, has a bearing on the ease with which the color can be ground in a varnish or lacquer to the requisite degree of fineness, so as to produce a smooth clean finish.

PIGMENTS OF ORGANIC AND INORGANIC ORIGIN

All pigments were originally found in or derived from nature, and many coloring matters have been dug out of the ground for centuries. They are roughly divided into three classes: inorganic pigments derived from mineral or metallic sources, organic pigments derived from living organisms or coal-tar products, and pigments made by a mixture of the two, such as organic dyes precipitated on metallic salts.

Certain types of colors that we are using today were used before the days of Tut-ankh-amen and have not been improved upon, either economically or chemically, for centuries. No economic advantage is realized by trying to reproduce them in the laboratory or in the plant. I refer to colors like French ochre, raw and burnt

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umber, raw and burnt sienna, the iron-oxide reds, and green earth.

Some pigments that were rare coloring matters in ancient days are now produced artificially much more economically and in a much purer form, as a result of chemical research. Ultramarine blue was formerly dug out of the ground as a semi-precious stone, known as lapis lazuli. Very little of it was found and it was always mixed with impurities. Cinnabar, or Chinese vermilion, once a product of nature, is now made by combining mercury and sulphur.

How Colors Are Produced Synthetically

One of the first colors to be developed synthetically was chrome yellow. It was made by combining chromic acid with lead. When potassium bichromate and a lead acetate solution combine, they form lead chromate, as a yellow pigment, and potassium acetate in solution. Chrome yellow is a very heavy pigment due to the presence of lead. Orange shades are obtained by introducing a small quantity of caustic alkali.

The makers of chrome green take the chrome yellow pulp, after it has been washed and allowed to settle, pour off the top liquid, and mix it with a pulp blue that also has been well washed, making in this way what is called chrome green. The pulp blue is known as Chinese blue, which is a double salt of iron and cyanogen.

Organic colors, such as carmine or pigments on the order of Van Dyke brown, which were originally derived from plants or animal organisms, have been used for centuries but are now rapidly falling into disuse because of their lack of permanency. It was also found that certain extracts from the roots of plants, such as the madder root, would precipitate on certain metallic or mineral bases like aluminum hydrate and form permanent colors. Of these colors, madder was the most permanent and still is the most permanent, although it is now made artificially under the name alizarine.

Next to this is rose lake, made from Brazil-wood extract, which is actually an extract of logwood precipitated on a whiting base. The other natural organic colorings, on the order of a Dutch pink, obtained from quercitron bark and Persian-berry extract, have no permanency and are utterly useless in the lacquer industry.

Fixing Organic Colors on Inorganic Bases

Old-fashioned carmine, which is an extract from an insect known as the cochineal bug precipitated on salts of tin and aluminum, gave the most brilliant red-maroon glaze that was ever used in the past. Its beauty of tone, however, has been equaled by more recent coal-tar derivatives, and carmine such as we have been using for years is rapidly falling into absolute disuse, due solely to its lack of permanency.

Before discussing the more highly colored organic matters, let us first understand what is meant by precipitating or fixing colors on a base. When it is desired to dye a piece of cotton fiber a purple color, for example, the cotton is saturated with a chemical mordant that will combine with the dyestuff and actually precipitate, or bind, the dye upon the cotton fiber. In making a pigment with the ordinary dyestuff, whether it be a vegetable extract or a synthetic derivative of coal tar, the cotton fiber is replaced with a white mineral base, and the dye is precipitated on this white powder in the same way that it would be fixed on a piece of cloth. This gives the so-called lake colors. Of course, the presence of a mineral or metallic base in these lake colors added greatly to the gravity of the pigment by increasing the density, and caused the settling that usually occurs with colors of this sort when made into color varnish.

Density Reduced by Organic Base

The next step in the color industry was to produce a purely organic pigment in which not only the coloring matter but the base as well would be organic, so that the finished pigment would have the same specific gravity and the same density as the dyestuff itself. About 15 or 20 years ago such a color was developed and was put on the market under the name of para toner. This was para-nitro-aniline precipitated on a beta-naphthol organic base. In the last steps in the development of this color, a yellow solution of para-nitro-aniline that has gone through many stages of treatment before it is ready to combine, is mixed properly with the base solution of beta-naphthol, and the color and base are formed instantaneously within each other. The resultant pigment is so light in gravity that it will not settle out of the water solution. It can be washed out only by pumping the solution through a filter press and forcing water through it under pressure.

When para toner was first put on the market it was regarded as the last word in red pigments. It is non-settling, is absolutely permanent, is a solid covering, and is very light in gravity. But it has one fault, it bleeds slightly when crossed with white, even in varnish. Since that time, a red has been perfected that has all the good qualities of the para reds plus that of non-bleeding in varnish. It is practically the most perfect red pigment in the world today and is known as para-nitro-toluidine.

If it were possible to make a complete line of colors having the properties of toluidine red and that would also resist the solvent action in cellulose thinners, including a blue, a green, a yellow, and a maroon, many of the troubles that now beset the trade would be eliminated. As it is, the makers of lacquer and colored enamels are constantly compromising and adjusting mixtures of perfect pigments with medium-grade pigments to produce the best possible product for the trade. At present, we have a yellow toner that is purely organic, non-settling and permanent; a high-grade maroon of the same order; the toluidine red just mentioned; and a green made from yellow toner plus a small percentage of Chinese blue, which in itself is very strong and shows little tendency to settle.

Blues Act Chemically on the Carrier

Anyone who has had any real experience in finishing high-grade automobiles will be able to put his finger on the one outstanding weakness in the entire line of pigment colorings on the market. This weakness is, of course, in the blues in general. The great trouble with the blue pigments has been that the one and only truly permanent brilliant blue, when ground in the ordinary varnishes or lacquers now in use, becomes chemically active and tends to destroy rapidly the carrier in which it is incorporated. On the other hand, the blues that work well with the various mediums in which they are ground either lack permanency or are wholly devoid of brilliancy and beauty of tone.

The permanent, brilliant, but chemically active blue is ultramarine, which is the synthetic formation of what was originally known as lapis lazuli. Ultramarine blue is a true glass formation and contains, among other elements in solid solution, active basic salts. When this blue is ground fine enough for use in automobile painting, it develops a distinctly alkaline reaction, which, in

the presence of moisture and sunlight, soon destroys the varnish or lacquer in which it is incorporated.

Finely powdered glass would be supposed to be the most inert translucent pigment that could be obtained, but when it is ground in an ordinary rubbing varnish and the finish is applied, the action between the supposedly inert glass and the varnish soon becomes apparent. The same thing happens, to a lesser extent but just as surely, when ultramarine blue is ground in the varnish.

The second type of blue mentioned, which possesses permanency and good working properties but lacks the brilliancy and beauty of ultramarine, is known as an iron blue. Whether it be the Chinese or Prussian type makes no difference. The manufacturer of colored lacquers for automobile use is practically forced at present to use these iron blues, although they have a tendency to develop a bronze finish that is objectionable. However, this class of blue can be obtained with the bronzing characteristic reduced to about one-quarter of what it was originally, and when a small quantity of white is added to produce the ordinary shades required by the trade, this difficulty of bronzing is practically eliminated.

Good Maroon Lacquers Are Available

The other weak sister in the coloring of automobiles today is found among the maroon pigments. Maroon lake, known as an amaranth, was found to be practically permanent in a varnish finish but when used in the lacquer type of finish fades rapidly and is practically worthless.

So much trouble was experienced with maroons in the early days of lacquer finishes that one large manufacturer went so far as to state that a satisfactory maroon lacquer was impossible. This has held back their use considerably and is in no way true. It is possible to obtain maroon lacquer finishes that are just as permanent as any maroon ever used in the old varnish finish. They are higher priced because they are developed from alizarine madder lakes, but they can be obtained and will give real satisfaction.

The only present drawback with the brilliant maroon pigment is its lack of covering properties in the deeper shades. The more brilliant deep-maroon pigments lack opacity to a marked degree and may be used only over a suitable ground coat. The solid-covering light-maroon pigments, on the other hand, lack depth of tone and brilliancy.

That any ordinary alizarine lake will not do when ground in lacquer is true. It must be especially well made and developed or the finished enamel will be decidedly brittle. Also, if the ordinary form of maroon toner is used, a distinct chemical action takes place in the can and a precipitation of both color and cotton will result. When carefully selected under competent laboratory experts, however, no difficulty is experienced in supplying the trade with any shade of maroon between wide extremes.

White Body-Pigments and Base-Extenders

White pigments can be divided into two classes, the opaque white body-pigments and the transparent white base-extenders. White pigments are all derived from mineral or synthetic metallic sources. No organic or vegetable white pigments are used successfully today. White lead is a basic carbonate of metallic lead. White zinc is an oxide of zinc, and titanox an oxide of titanium. Lithopone is a sulphate of zinc precipitated on barium sulphate.

Research has not yet developed a suitable use for white lead in the lacquer industry, owing to the fact that this pigment tends to thicken or "liver" in any of the ordinary cellulose lacquers now on the market. White zinc, titanox and lithopone are being used successfully at the present writing.

The white base-extender pigments are typified by blanc fixe, or barium sulphate; calcium carbonate, commonly known as whiting; aluminum hydrate; calcium sulphate, or gypsum; and silex, or silicon dioxide. These white base-extenders, when wet with varnish or lacquer, are semi-transparent. They are used as bases on which to fix organic dyes, or as extenders to weaken and cheapen strong pure colored pigments.

Most of the black pigments, unlike the white ones, are of organic and, very often, of animal origin. The bone and ivory blacks are obtained by calcining actual animal bone or ivory chips, while the carbon and lamp blacks are obtained through the incomplete combustion of hydrocarbon oils and gases. The charred-carbon content determines the black element in these pigments. That a bone black containing but 20 per cent of pure carbon may be 20 or more shades darker than a pure carbon black of 99-per cent actual carbon-content is strange but nevertheless true. All types of black pigment that were once used in the varnish industry can be used in cellulose lacquers.

Colors Available for Cellulose Lacquers

Now let us consider what color-pigment palette we have left for use in cellulose lacquers as compared with the extensive palette available for gum and oil varnish. Research gives, in the reds, only toluidine bright red, helio Bordeaux maroon and a developed alizarine wine color. Of course, the iron-oxide reds, including the Venetian and the Indian, which have been handed down to us from the past, are available. We dare not use, at present, the long line of para reds, the azo scarlet lakes, the American eosine vermilions, the lithol reds on orange mineral bases, or the amaranth and rose lakes.

In the yellow group, we have the chrome-lead yellows, ranging from light lemon to deep orange; the zinc-chrome yellows and an organic yellow toner known as hansa yellow. Here, again, we can still use the well-known raw sienna of the iron group. All the yellow lakes, due to their lack of covering body and fugitive qualities in light, must be eliminated.

In the green-pigment group we may include all shades of standard chrome greens, guignet green, which is an oxide of chromium and practically the most permanent green in the world, and toner greens made from hansa yellow mixed with Chinese blue. We cannot use any of the ultramarine-blue greens, and Paris green, due to its lack of covering quality, is suitable only as a tinting color.

As was pointed out in the beginning, the lacquer industry has been forced to the use of one type of blue, the iron blue, either of the Chinese or Prussian variety. Ultramarine is taboo and aniline-blue lakes, even including helio marine, have been eliminated.

At present, in the purple pigment group, we have but one safe choice. That is a highly developed alizarine purple of great brilliancy and tone but decidedly lacking in opacity.

When one considers the solvent action of lacquer thinners that a pigment must withstand today as compared with the mild action of turpentine or mineral spirit in the past, one marvels that we have so many suitable pigments for use in cellulose lacquers. Moreover, the

lacquer coating is so thin compared with that of the old varnish-color days, that we find the action of light much more severe, and many of the colors that stood up perfectly in the past had to be eliminated on that account alone.

However, this pigment palette, as left to us, is more than sufficient for our needs, especially when we realize the countless shades and tints and grays that can be obtained by combining any of the approved pigments with black and white. We may rest assured that, with all the research work now concentrated on the development of cellulose lacquers, the production of high-grade synthetic pigments will receive an added impetus, and the next few years should bring forth a longer line of ideal brilliant color pigments than we have ever supposed would be possible.

DETERMINATION OF CARBON MONOXIDE IN BLOOD

CARBON monoxide may be formed in many places and inhalation of this insidious gas is a frequent and widely distributed cause of poisoning that ranges in severity from headache and lassitude to unconsciousness and death. People are continually being affected by carbon monoxide in homes and garages, around gas and gasoline engines and blast furnaces, in fighting fires, after blasting in mines and quarries, and after mine fires and explosions; in fact, at any place where there is possibility of exposure to the products of combustion of carbonaceous fuels or products. As cases of this type of poisoning often occur from the most unsuspected sources, and as the indicating symptoms of carbon monoxide poisoning, such as headache, nausea, dizziness, collapse, and unconsciousness are often attributed to other causes, it is essential to have suitable means whereby the true condition can be ascertained. Quick, accurate determination is not only of value for making diagnoses and giving proper treatment, but for investigating the causes and conditions under which the poisoning occurred, as well as providing means for examining doubtful atmospheres to prevent and guard against the recurrence of poisoning.

The only infallible diagnosis of carbon monoxide poisoning is made by examination of the blood for carbon monoxide hemoglobin, the compound that the gas forms with blood and through which it possesses noxious properties. A mere qualitative examination for this compound will indicate whether or not carbon monoxide is present, but in view of the obvious desirability of knowing whether or not carbon monoxide is the primary cause of the condition of the patient, it is necessary to make a quantitative determination of the carbon monoxide hemoglobin present.

Methods have been devised for the quantitative analysis of carbon monoxide when present in blood and in air in quantities large enough to be dangerous to the health and safety of a person. Some of them are suitable as to accuracy, yet all have some objectionable features in that they require elaborate and expensive apparatus, and special technique and training on the part of the analyst, or are too delicate and cumbersome for field use. The last factor is important in investigations pertaining to the cause, diagnosis, and treatment of this type of industrial and domestic accident.

The Bureau of Mines, in its investigation of many cases of industrial and domestic poisoning from carbon monoxide, found it necessary to develop a method and apparatus that could be immediately taken to the scene of a poisoning, and would give accurate results as to the carbon monoxide in the blood and in the air. The method, which is called the pyrotannic acid method, has been used frequently in the last 2 years in the investigation of fatal and non-fatal cases of poisoning from gas stoves, automobile-exhaust gases and blast-furnace gas; also in the analysis of air in vehicular tunnels and in mines after blasting and during rescue operations after a mine explosion. It has been used in the laboratory for experimental investigation of carbon monoxide poisoning of men and animals and also with equal success by other investigators and by corporations both in America and in foreign countries. In all of this work the method has been found very reliable and accurate, and admirably fulfills requirements for the examination of blood and air. Its simplicity and ease of operation make it well suited to the needs of hospitals, industrial surgeons, safety engineers, coroners, departments of public safety, boards of health, and other allied organizations.—R. R. Sayers and W. P. Yant in Bureau of Mines Technical Paper No. 373.

CHARLES L. NEDOMA

CHARLES L. NEDOMA, who since 1917 has been the secretary of the engineering department of the Cadillac Motor Car Co., died Dec. 23, at the home of a friend in Detroit, aged 49 years. He was born at Vranam, Bohemia, now Czecho-Slovakia, and received his education at the commercial academy and the university in Prague.

He came to this Country in 1910 and established his first connection with the automotive industry on Feb. 1, 1915, when he became engineering data clerk with the Chalmers Motor Car Co., Detroit. On Aug. 15, 1917, he left to become secretary to the chief engineer of the Cadillac Motor Car Co. In this position, which he held continuously until the time of his death, Mr. Nedoma had charge of the engineering records of the Cadillac organization.

Mr. Nedoma was elected to Associate Member grade in the Society on Oct. 30, 1918.

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Airplane and Airship: Their Spheres of Economic Usefulness

By H. F. Parker[1]

Annual Meeting Paper *Illustrated with* Charts

Abstract

ALTHOUGH the generally accepted spheres of usefulness of the airship and the airplane are usually based on their comparative ranges of operation and their speeds, the suitability of either of these types for a given purpose is primarily dependnt on two classes of factors, those fundamentally dissimilar and those roughly similar. Conclusions as to relative usefulness should be based on a consideration of the dissimilar characteristics, which include aerodynamic efficiency, size and comfort.

Aerodynamic efficiency governs range and, since it determines fuel consumption, influences the cost of operation. The size required depends on the paying loads that are available for carrying. Comfort concerns passenger-carrying only.

As the propeller efficiency, rate of fuel consumption and ratio of weight of fuel carried to gross lift are similar in both types of aircraft, the range must depend on the L/D factor, that is, the ratio of gross lift to thrust. Although it is not customary to apply this ratio to airships, comparative curves for the airplane and the airship on this basis show a surprising superiority for the airship, not only at speeds of 60 or 70 m.p.h. but at higher speeds that have not yet been attained. In the matter of fuel consumption, an airship of 150-ton capacity traveling at 70 m.p.h. requires only one-quarter the fuel per ton-mile, and at 105 m.p.h. only one-half the fuel per ton-mile that is needed to propel 1 ton of airplane 1 mile at either speed.

Partly nullifying the advantage of the airship because of lower fuel-consumption has been the waste of lifting-gas that occurs in maintaining equilibrium when the weight has been reduced by the consumption of fuel. Notwithstanding this waste the airship can still compete with the airplane on an equal basis in the matter of fuel consumption at a speed of 70 m.p.h.; but through water-recovery and hydrogen-burning the waste is no longer necessary.

With regard to size, consideration is given to the effect of dimensional laws on the dead-weight of both types of aircraft. Assuming that the dead-weight of airplanes increases with the increase in size under the 3/2 law, the further assumption is made that 10 tons is the weight at which the law begins to operate; in airships, the factors operating are different from those of airplanes and do not become effective until sizes are reached far in excess of those contemplated at present.

Asserting that airplanes and airships of the same size are not likely to come into direct competition, the author then examines the fields in which each type is likely to prove useful.

Among the conditions affecting the comfort of passengers are found to be the relative amounts of space available on the two types of craft, and the various motions encountered, such as rolling, pitching, bodily vertical motion, and vibration.

But the observations made from the standpoints of aerodynamic efficiency, size and comfort, are said to be subject to modification by additional factors, of which the most important are (*a*) initial percentage of useful load, (*b*) initial cost per unit of gross weight, (*c*) relative operating-costs, (*d*) insurance and safety, and (*e*) rate of depreciation, each of which is discussed in detail; and reference is made to the causes leading to the Shenandoah disaster.

The conclusions reached are that, on account of aerodynamic superiority, the airship will be used wherever possible for carrying passengers in comfort, but a large field exists in which it cannot be used because of insufficient loads; that the airship will continue to be a long-range, the airplane, a short-range vessel, but these distinctions will be affected largely by the volume of traffic available; that although the cost of transportation per ton-mile is greater by airplane than by airship, this fact will not seriously limit the use of the airplane within its own field, the comparative magnitudes of the fields of heavier-than-air and lighter-than-air operation being similar to those of rail and water transportation; and that, inasmuch as the two types are complementary, the successful operation of either one will react to the benefit of the other.

THAT the airship is a long-range, the airplane, a short-range vessel, and that the airplane is inherently much the master craft, are generally accepted. Estimates of their spheres of usefulness are usually based on these generalizations and, in most instances, are true. This is not necessarily the case, however; and an attempt will be made in this paper to show that the suitability of either of these types for a given purpose is primarily dependent on other factors. These factors can be divided into two classes, those in the first class being fundamentally dissimilar, those in the second class, roughly similar, at least in the present state of our knowledge of the art. Conclusions as to spheres of usefulness should be based on a consideration of the dissimilar characteristics, which appear to be inherent; but such conclusions are subject to modification, if a divergence should appear in the factors that are considered similar in the light of our present knowledge. The dissimilar characteristics should, therefore, be considered first; and the possible effect of changes in the similar characteristics will be discussed afterward.

Dissimilar Characteristics

The dissimilar characteristics are three in number: (*a*) aerodynamic efficiency, (*b*) size and (*c*) comfort. Aerodynamic efficiency governs the range and, since it determines the fuel consumption, influences the cost of operation also. In the case of the airship, it is a variable factor depending on both size and speed; in that of the airplane, it is practically independent of them. Although dependent to a certain extent on the state of the art, this difference is so great that it is subject to slight change only because of possible changes in relative efficiency due to improvement in form.

The second factor is size; the airship is inherently a

[1] Philadelphia.

large craft and, whatever its efficiency, can be used only when the load is large enough to fill it reasonably. If the unit load available per trip is not sufficiently large, an aerodynamically efficient craft running empty will be superseded by a less efficient craft having a larger percentage of its available space filled with a paying load.

The third factor, comfort, concerns passenger-carrying only but is likely to have great influence in determining the choice of types when other considerations are approximately equal.

Aerodynamic Efficiency

Consider first the question of range. The generally accepted superiority of the airship is illustrated in Fig. 1. As this figure would tend to give the impression that this advantage is inherent, it is desirable to analyze the fundamentals on which range depends, to determine whether this is so.

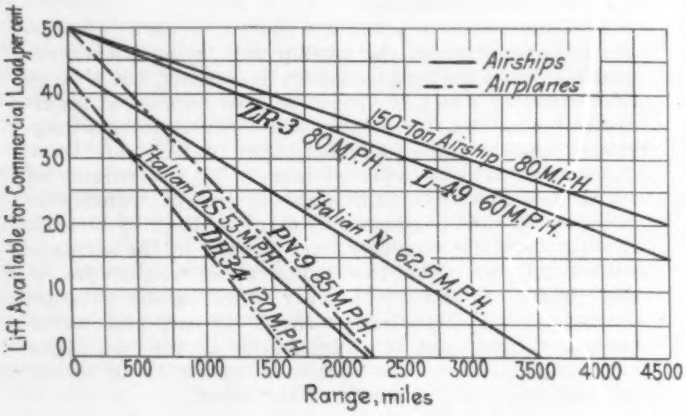

Fig. 1—Comparative Range of Airplanes and Airships
Although the Figure Gives the Impression That an Advantage Is Inherent in the Airship, Analysis Shows It To Be Dependent on the L/D Factor, Which Is Not Usually Applied to Airships

The range of any type of aircraft may be expressed by the following formula

$$R = (375\eta/F) \times (w/W) \times (L/D)$$

where

η = propeller efficiency
F = rate of fuel consumption, in pounds per brake horsepower-hour
L/D = gross lift/thrust
R = range of aircraft, in miles
W = gross lift of aircraft
w = weight of fuel carried

Three of these factors, η, F, and w/W, are similar in both types of aircraft, so that any difference in range must be dependent on the L/D factor.

The use of this L/D ratio is not customary in connection with airships, and it may not seem valid to do so. In heavier-than-air work, this ratio represents the relation between two dynamic forces; in lighter-than-air, between a static and a dynamic. In its primary conception, the term expresses the relation between the vertical and the horizontal components of the resultant force of the air against an airfoil. In a broader sense, it can be applied to the airplane as a whole, and is still perfectly valid. In this sense, L equals the weight of the machine and D the sum of all the resistances. As the total resistance must equal the thrust of the propeller, this use of L/D gives a relation between the power and the weight.

Comparison of L/D Ratios

It can thus be applied to airships, and a comparison between the L/D ratios of the two types reveals some interesting features. The most important is the fundamental difference in the shape of the curves when L/D is plotted against speed. That for an airplane has a definite maximum which is receded from with any change from the optimum speed. The exact speed at which this optimum point is located is a matter of design but, in any given machine, higher or lower speeds invariably involve a falling-off of efficiency. At higher speeds, the parasite resistance increases rapidly. The optimum speed occurs at an angle of incidence greater than the optimum for the wings alone. The falling-off is therefore slow at first, the loss due to parasite resistance being partly balanced by a reduction in wing resistance. Above the speed at which the wings give their maximum L/D, both factors are unfavorable and the falling-off is rapid. With a decrease of speed below the optimum, the converse holds true. The parasite resistance is less but the wing resistance rapidly increases. The result is a gradual falling-off of the over-all efficiency.

In the case of the airship, the shape of the curve is not dependent on a balance between two independently varying forces, but no one force alone, which corresponds to the parasite resistance of the airplane. The curve is asymptotic, approaching infinity at zero speed and zero at infinite speed.

Explanation of Curves

Fig. 2 has been drawn to illustrate this point. In this case, inherent characteristics are still somewhat masked by efficiency of design. "Form" constants have therefore been chosen arbitrarily, and Fig. 3 has been plotted with the same coordinates as Fig. 2. Nine has been taken as a figure for the L/D representing good present-day airplane design, while for the airship the efficiency has been calculated on the basis of a coefficient $C = 0.0115$, which is derived from the equation

$$R = C\rho V^{2/3}v^2$$

Both have been exceeded, but afford a fair basis of comparison. In this figure, then, the variable efficiency of the airship is directly comparable with the constant efficiency of the airplane.

The curves indicate a surprising superiority for the large airship, not only where it might perhaps be expected, at speeds of 60 or 70 m.p.h., but even at 100 m.p.h. and above, speeds not yet attained by an airship. It also shows that the very small airship, even on the assumptions here made, has no superiority at commercial speeds.

The effect of these characteristics on fuel consumption is shown in Fig. 4. From this curve it will be seen that an airship of 150-ton capacity traveling at 70 m.p.h. requires only one-quarter the fuel per ton-mile, and at 105 m.p.h. only one-half the fuel per ton-mile, that is needed to propel 1 ton of airplane 1 mile at either speed. Airships of this size, 5,000,000 cu. ft., are actually under construction, so this great advantage would seem to be attainable.

Waste of Lifting-Gas

In discussing fuel consumption and claiming such an advantage for the airship, it is necessary to consider the effect of an expenditure proportional to the fuel consumption that in the past has tended to negative this advantage. I refer to the waste of lifting-gas that occurs in maintaining equilibrium when the weight has been reduced by the consumption of fuel.

Assuming $0.25 per gal. as the price of aviation gasoline, and $5.00 per 1000 cu. ft. as the cost of hydrogen, then, for every $100 spent on fuel it has been necessary to waste $176 on hydrogen. Thus, even when wasting hydrogen, an airship of 150 tons can compete with an airplane in fuel consumption on an equal basis at 70 m.p.h.

Fortunately, this waste is no longer necessary, two methods being now available for dealing with it. The first is through water recovery, which has been developed in this Country and completely eliminates the waste; the second, hydrogen burning, has been developed in England and puts the hydrogen to a useful purpose.

Water Recovery

When water recovery is used, the lifting-gas losses are reduced to those due to diffusion and to superheat. According to Colonel Crocco, who has been responsible for

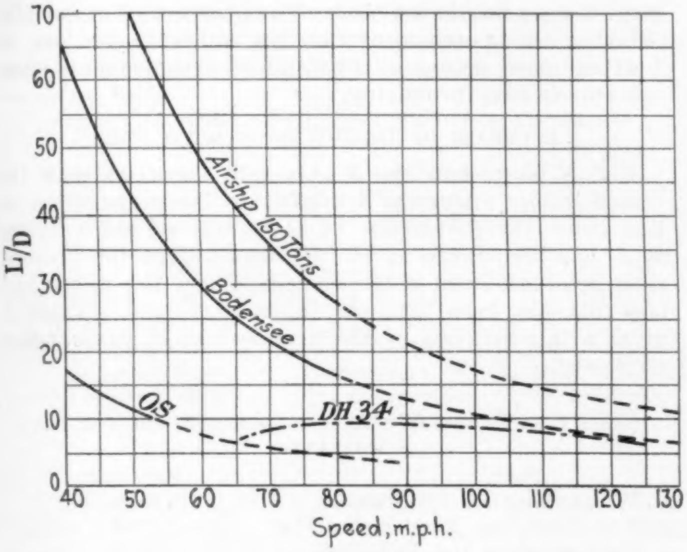

FIG. 2—CURVES SHOWING THE VARIATION OF THE L/D RATIO WITH SPEED IN AIRSHIPS

The Shape of the Curve Is Not Dependent on a Balance between Two Independently Varying Forces, but on One Force Alone, Which Corresponds to the Parasite Resistance of an Airplane. The Curve Is Asymptotic, Approaching Infinity at Zero Speed and Zero at Infinite Speed

many of the Italian developments in semi-rigid airships, those due to diffusion need not exceed per annum 20 per cent of the volume of the ship. This figure may be optimistic, but a most generous allowance for carelessness in practical operation would place the loss at less than 100 per cent per annum. With commercial ships in regular operation, a loss of this magnitude would be only one-twentieth of that necessary without water recovery. Water recovery also materially reduces the effect of superheat. With the weight of the airship constant throughout a flight, the "false lift" is dependent only on the excess temperature of the gas; without water recovery 12-hr. fuel-consumption must be added to this figure. As these two amounts are roughly equal, and would be equal in a 150-ton airship burning 1000 lb. of fuel per hr. and subject to 20 deg. fahr. of superheat, the effect of superheating is reduced one-half. This reduction is important, for, whereas it was necessary formerly to valve in addition to taking advantage of the dynamic lift, superheat can now be handled by dynamic means alone without the loss of gas. The use of dynamic lift, though better than wasting lifting-gas, is not, however, an ideal way of dealing with the situation, for it causes increased drag and, hence, involves an increase

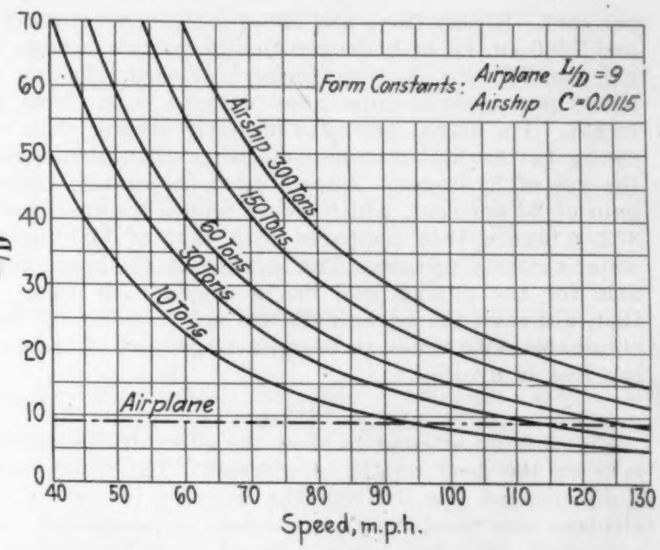

FIG. 3—CURVES SHOWING THE SURPRISING SUPERIORITY OF THE LARGE AIRSHIP

The Variable Efficiency of the Airship Is Directly Comparable with the Constant Efficiency of the Airplane. The Form Constants Have Been Chosen Arbitrarily and the Same Ordinates Used as Those of Fig. 2

in the fuel consumption. That this drag can be overcome by the maintenance of constant superheat, which is obtained artificially at night from air heated by the water-recovery apparatus, and without it when natural superheat is available is possible. Water-recovery apparatus now in use weighs less than 1 per cent of the gross lift of the airship, so the price paid for the process is very reasonable.

Hydrogen Burning

In the case of hydrogen burning, the lifting-gas is used as fuel. Less liquid fuel need be carried, increasing the space available for the commercial load and reducing the outlay on liquid fuel. The gross fuel-charge is less than when hydrogen is valved, although it is in excess of that possible with water recovery.

It requires 8800 cu. ft. of hydrogen to lift 100 gal. of gasoline, and the heat-value of the hydrogen almost equals that of 20 gal. of gasoline, so the net gain is 20

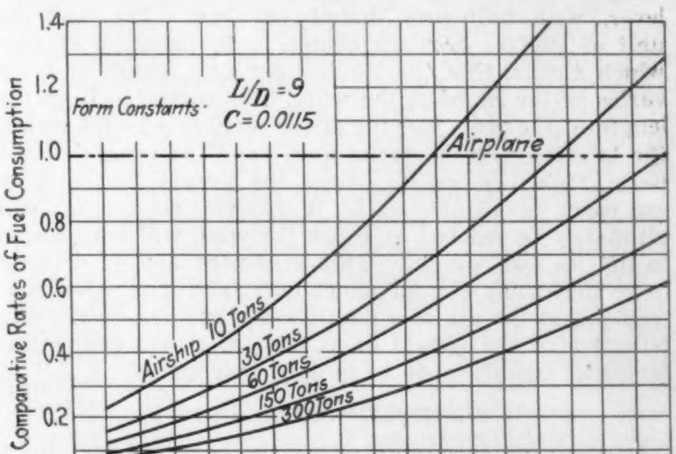

FIG. 4—COMPARATIVE FUEL-CONSUMPTION

An Airship of 150-Tons Capacity Traveling at 70 M.P.H. Requires Only One-Quarter the Fuel per Ton-Mile, and at 105 M.P.H. Only One-Half the Fuel per Ton-Mile, That Is Needed To Propel 1 Ton of Airplane 1 Mile at Either Speed

per cent. Eighty-three and one-third gallons of gasoline and 7250 cu. ft. of hydrogen therefore serve where 100 gal. and 8800 cu. ft. were formerly needed. Taking the prices previously assumed, the fuel cost is cut from $69 to $57. The actual saving is probably greater than this owing to the higher engine-efficiency that accompanies the use of hydrogen. Advocates of the system claim a gain of 33 per cent, which would reduce the fuel cost to $52, a figure that compares with that of $25 for the water-recovery process. The increase in the space available for the paying load has a considerable value, so that, although the advantages are not so great as those obtainable with water recovery, a large part of the valving loss is avoided.

Size

Fig. 5 is an attempt to show the effect of dimensional laws on the dead weight of aircraft. The existence of a dimensional law limiting the increase in size of the airplane was pointed out very early in its history, and predictions were made that it would never be possible to build an airplane capable even of crossing the Atlantic Ocean. This had the unfortunate effect of throwing discredit upon the theory; and a somewhat natural reaction was that practical men stated with equal boldness that no limit existed to the size of airplanes that might ultimately be built.

It is my purpose at present not to predict any new exact limit beyond which airplanes cannot be built, but to point out that unfavorable factors come into play as size is increased and that these factors will probably cause airplanes much in excess of the sizes in use at present to be less efficient than small or moderate-size ones, so that, as a result, the craft actually used will be likely to remain of moderate size. To make a few definite assumptions and to consider their effect on the dead-weight of the craft may be of interest.

Relation of Weight to Load

The weight of the structure of all aircraft increases at a greater rate than the load that can be lifted by it. In the case of the airplane, the lift is dependent on the area of the wings, which, in geometrically similar craft, varies as the square of a linear dimension, say as L^2. The weight of the wings, however, varies as L^3. The wings may be considered as beams, usually double-cantilever, with uniformly distributed load. The load per unit of surface does not change with variation of size, which means, that the loading per unit length of beam varies as the chord of the wing, that is, as L. With the length of the beam varying at the same rate as the chord, the bending-moment varies as L^3, and the weight of the beam, therefore, as L^3. Since the weight that a wing can carry varies only as L^2, it follows that a point will ultimately be reached at which the wing will not be able to lift its own weight. This argument applies directly to geometrically similar wings only; and it is often contended that the use of a multiplane structure, or the distribution of the weight along the wing, will enable unfavorable conditions to be escaped indefinitely.

Distribution of Weight

Distributing the weight along the beam merely alters the condition of loading of the beam; instead of being a double cantilever with the load concentrated at the center, the load can be distributed and the beam can possibly approximate to a continuous one. Some benefit may be obtained from this loading, although practical objections, especially in the nature of landing-shocks, render it doubtful. The law, however, still remains: a modified type of beam increasing in weight at a greater rate than the weight it lifts.

The same thing holds for the use of a multiplane structure. The increase in length of the beam may apparently be checked by using more beams of shorter length. In practice, however, it appears that the gain from this source is balanced by a loss in aerodynamic efficiency. The change from monoplane to biplane increases the effective depth of the beam approximately eight times, and reduces the length for similar aspect-ratio to 0.707 of its monoplane value. It barely pays to make this change; and monoplanes can exist in competition with biplanes. The increase from biplane to triplane merely doubles the effective depth of the beam and reduces the length to 0.815 of its biplane value. This does not pay in normal-size machines but appears to be a cheaper expedient than facing the 3/2 law in craft of the largest sizes now being built. The prospect of materially delaying the operation of this law either by the use of four or more planes or by tandem arrangements does not appear very promising.

Increase of Dead-Weight with Size

Fig. 5 shows how the dead-weight increases with increase in size under the 3/2 law. In the preparation of this curve the percentage of the gross weight varying as L^3 has been taken as 10, the dead-weight for present sizes being assumed at 50 per cent, a very low figure but one that has been attained in good designs. Table 1 gives a fair analysis of the dead-weight of present-day airplanes[2].

TABLE 1—ANALYSIS OF THE DEAD-WEIGHT OF PRESENT-DAY AIRPLANES

Part	Per Cent	
Wings Complete with Bracing	15.00	
Tail, Elevators, Rudder, and Fin	2.00	
Undercarriage and Tail-Skid	4.00	
Body with Engine Mounting, Seating and the Like	11.25	
Machine and Engine Controls	0.75	
Total Weight of Structure		33.00
Engine	18.50	
Radiator, Shutters and Cowling	2.75	
Cooling-Water	2.75	
Fuel and Oil Tanks	3.00	
Piping, Cocks and Pumps	0.50	
Propeller	2.50	
Starting-Gear for Engines	0.50	
Total Weight of Powerplant		30.50

Powerplant Weights

Powerplant weights vary at the same rate as the lift, that is, as L^2, while for our present purpose the body, undercarriage, tail surfaces, and the fabric of the wings are assumed to do likewise. Tail surfaces theoretically vary as L^3, but are capable of refinement of design with increase in size, just as the main wings have improved up to about 10,000 lb., gross weight. Both body and undercarriage increase at a greater rate than L^2, though at less than L^3. It is believed that, by leaving these factors out of account and reducing the wing percentage to 10, the resulting curve will become very conservative.

The L^3 law begins to make itself felt in the design of wings in machines having a gross weight of 10,000 lb. However, to allow a lower factor of safety in machines

[2] See *Flight*, Feb. 14, 1924, p. 92.

larger than this, is customary, so that the effects of the law are dodged until the factor of safety reaches a lower limit; this can hardly be less than one-half the factor at 10,000 lb., so that 10 tons has been assumed to be the weight at which the law begins to operate. The curve is based upon this assumption.

Somewhat similar conditions exist in the case of the airship; a limit on the maximum size possible exists, though the factors determining the limit are different from those operating in the case of the airplane and do not become effective until sizes are reached far in excess of anything contemplated at present. On the other hand, an actual improvement in performance may be expected with increase in size, at least in sizes up to 300 tons.

In this case the lift varies as L^3, while the main structure[3] varies as L^4 and the powerplant, outer cover and gas cells vary as L^2 only. At first, the saving in the last group more than balances the loss from structure weight, but ultimately the latter becomes the controlling factor and the total dead-weight increases.

In preparing the airship curve shown in Fig. 5 the dead-weight has been divided up as given in Table 2.

TABLE 2—DIVISION OF THE DEAD-WEIGHT OF AN AIRSHIP

	Per Cent
Weights Varying as L^4: Longitudinal and Transverse Framing with Wiring	16
Weights Varying as L^3: Control Surfaces, Rudders and the Like; Control and Passenger Car; Secondary Structures, Walkways and the Like, and Mooring System	10
Weights Varying as L^2: Powerplant, Engine Cars and Fuel System, 14 Per Cent; Outer-Cover of Gas-Cells, Netting and Valves, 10 Per Cent; Total	24
Grand Total	50

These percentages are based on the standard lifting-power of hydrogen, 68 lb. per 1000 cu. ft., and upon actual weights in the ZR-3.

From the curve in Fig. 5 it is obvious that, although an upper limit exists for the airship, it is not likely to bother us for a very long time, if at all. The lower limit will make itself felt, especially as the curve takes no account of the greater unit-weight of construction in the smaller sizes. A small airship is further handicapped by its inherently low L/D, as is shown in Fig. 2, and by a poor form-constant, ships actually built having a coefficient far in excess of 0.0115. Therefore, that airplanes and airships of the same size are never likely to be in direct competition is apparent, the field for the small sizes being held by the airplane and that for the large sizes by the airship, with a probable gap between the sizes of the two types.

COMPARISON OF USEFUL FIELDS

Given this division into groups for the small and the large sizes, it becomes necessary to examine the fields in which each type is likely to prove useful.

The primary value of aircraft lies in its property of saving time. This is based on its great advantage in the actual speed of transit, modified by the time-loss in covering the distance from the actual starting-point to the departure airdrome, and from the arrival airdrome to the final destination. It is also greatly modified by the time-interval between the departures; and aircraft are not likely to be of real utility as time-savers until this time-interval has been reduced to a proportion of

[3] See *Aeronautical Journal*, July, 1920, p. 386.

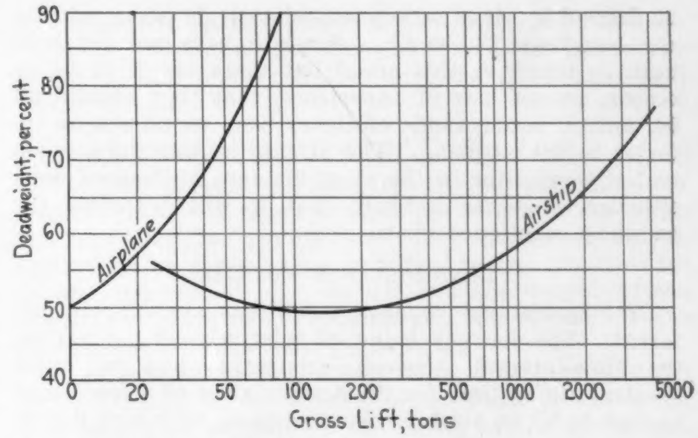

FIG. 5—EFFECT OF DIMENSIONAL LAWS ON THE DEAD-WEIGHT OF AIRCRAFT

As the Size Is Increased, Unfavorable Factors Come into Play That Will Probably Cause Airplanes Much in Excess of the Sizes in Use at Present To Be Less Efficient than Small or Moderate-Size Ones

the total time of transit similar to that existing in other forms of transportation.

It can be shown that, wherever a reasonable volume of traffic exists, the interval between departures does not exceed one-half the elapsed time of the voyage; in many cases, the interval is very much less. The limiting routes are those halfway round the world, from England to New Zealand and Australia. The elapsed time for the mail service in these cases is about 4 weeks; the time-interval between departures from New Zealand is 2 weeks, and from Australia 2 weeks or less. From the City of Washington to New York City by train is a 5-hr. journey; during the daytime, the time-interval between departures is about 1 hr. Consider also the crossing of the Atlantic Ocean. During the summer months, sailings of fast and moderately fast passenger-vessels from America to England and the English Channel ports average 3 per day in each direction. For practical purposes, however, the unit of time in this case is a day, and the elapsed time about 8 days, giving a ratio much below the one-half considered as a limit.

TIME-INTERVAL OF AIR SERVICE

In the case of aerial services, such a ratio of time-interval to elapsed time will not be established for a considerable period after the initiation of the service. Few passengers can be expected in the beginning, and the use of small machines at rather long intervals will be required. The tendency then is likely to be an increase in the number of departures rather than in the size of the machine until a reasonable ratio of the time-interval to the elapsed time has been established.

Short-distance flights, being of short duration, are likely to call for frequent departures, and the number of passengers offering during these short intervals will in most cases also be small. Except in very rare cases, they will not be enough to fill reasonably an airship large enough to be efficient. For short-distance voyages, the highest practicable air-speed is required. Here the airplane appears to possess a great advantage, which, however, may not be real. First, record-breaking speeds are always too expensive to approach in regular service. Thus, a speed of 120 m.p.h. has been attained on railroads, but the actual speed of trains practically never exceeds 60 m.p.h. It is rather early yet to attempt to predict commercial speeds for aircraft. However, a speed of from 90 to 100 m.p.h. is necessary to compete with railroads. A large volume of traffic may therefore

be carried by air at speeds only slightly in excess of this, say less than 120 m.p.h. Airships have not yet been built to travel at this speed but there seems to be no reason, except lack of experience, that they should not be, and in aerodynamic efficiency they would not be inferior to the airplane. The airship is, therefore, a potential competitor in the short-distance high-speed field, although it seems unlikely that it will overcome the handicap mentioned above.

Long-Distance Voyages

On long-distance voyages, conditions are entirely different. The journey being of relatively long duration, the time-interval between departures can be much greater, giving time for the accumulation of a load large enough to fill an airship. Furthermore, very long flights are usually over the ocean, where the speed necessary to give a commanding advantage over the existing form of transport is much lower than on land. A speed of 50 m.p.h. is sufficient for this purpose; however, to operate airships at 70 m.p.h. is likely to pay better, partly because at this speed they can make more voyages and earn more money without materially increasing their running expenses, and partly because engine power for a speed in excess of this must be carried to overcome possible adverse winds, whatever within reason may be the schedule speed. The two cases considered above involve the saving of a few hours of one business day and the saving of several days.

A third important case exists when part of or perhaps a whole business day can be saved by increasing the distance that can be covered at night. The best example of this is the mail route between New York City and Chicago. At present the distance is covered by rail in the minimum of 20 hr., which, for practical purposes, involves the loss of a whole business day; by aircraft, it can be completed in the interval between the close of one business day and the beginning of the next, the actual flying-time being less than 12 hr.

This seems to be one of the very few fields in which both types of aircraft may come into competition, at least in the matter of carrying freight and mail. No competition in passenger-carrying is likely; an all-night flight on an airplane would hardly prove attractive to a prospective passenger except in a distinct emergency, for a reasonable night's sleep would be almost impossible. Apart from the general matter of comfort, to be considered later, an airplane would have to make at least one stop en route, which would effectively interrupt any sleep a passenger might have begun to enjoy. This objection, however, does not hold for mail and freight; but, as one departure only is necessary each night, the accumulation may well be sufficient to provide an airship with a reasonable load. Both types of aircraft would be able to complete the distance in the time available, so the more efficient should survive.

Comfort

The first factor affecting comfort is space. A certain minimum amount is absolutely essential or passengers will refuse to travel because of positive discomfort. Present commercial airplanes offer little more than this minimum. The space available would probably be sufficient for short flights were it not for the difficulty of obtaining ventilation and the increased likelihood of air sickness. Even with an ample supply of fresh air, an average passenger experiences a greater tendency to sickness when inside a cabin than when outside. To provide more space entails the expenditure of more power, to overcome the added drag due to the larger frontal-area of the fuselage. This expenditure can at present ill be afforded.

The airship is in a much better position and can provide adequate space at a very moderate increase of power; the price it must pay for a given increase of volume, as compared with an airplane of the same gross weight and speed, appears to be only about one-sixth of that necessary in the latter. This price is proportional to the increased drag, which varies approximately with the added frontal-area. As volume is the product of length and frontal area, the greater the length of the craft, the less need be the increase in area.

Compare the lengths of the aircraft shown in Table 3.

TABLE 3—COMPARISON OF GROSS WEIGHT AND LENGTH OF AIRCRAFT

Aircraft	Gross Weight, Lb.	Length, Ft.
Barling Bomber	40,000	65
Bodensee	53,000	400
Airship of 590,000-Cu. Ft. Capacity, Similar in Shape to the Shenandoah	40,000	440

It is apparent that, for a given weight, an airship is very much longer than an airplane; hence, the cost of space for passenger accommodation in an airship will be proportionately less.

Irregular motions have a very marked effect on the comfort of passengers; the discomfort due to them can be divided into the motions produced by (*a*) rolling, (*b*) pitching, (*c*) bodily vertical motion, and (*d*) vibration.

Rolling may be caused by a gust or a vertical current of air acting on one side of the aircraft only; and the disturbance is roughly proportional to the moment of rotation brought into play by the gust.

For the purpose of comparison, consider craft exposing the same plan-area. The areas on each side of the longitudinal axis are then the same, and the disturbance is proportional to the distance of the center of pressure from the longitudinal axis. Assume further, that the plan shapes are similar, that is, that the airplane wing is tapered toward the tip, in a curve similar to that of an airship. The wing shape is usually more nearly a rectangle, so this assumption will work in favor of the airplane. The distance of the center of pressure is proportional to the aspect-ratio, which may be taken as 8 to 1 for an airplane and as 1 to 7 for an airship, or, considering one-half the craft only, as 4 to 1 and 1 to 14. It follows that the disturbing moment in an airship is only 1/56 of that experienced by an airplane.

Correcting Moment

The actual motion that occurs is further dependent on the correcting moment available, both as to magnitude and as to the time-interval that elapses before it comes into operation. In an airship, the center of gravity is below the center of buoyancy, so an inherent correcting-moment is present. An airplane relies on correction by air forces, which must, for the most part, be applied manually through the ailerons. In practice, a time lag occurs before the pilot can make the necessary correction, and during this interval the unpleasant motion has occurred.

The above factors determine the magnitude of the motion; the period is of at least equal importance from considerations of comfort and is dependent on the moment of inertia. In an airplane, the weights are concentrated

near the center of gravity; in an airship, they are concentrated along the keel, so the cases are similar.

In practice, however, the center of pressure on an airship is so close to the axis that rolling occurs hardly at all, while on an airplane a motion of considerable amplitude and of short period occurs. Even with increased size, rolling would still occur under disturbing conditions and would be modified only by having a longer period. This would be an appreciable gain, but an airplane must always compare unfavorably with an airship, when this particular motion, for practical purposes, is absent.

The reasoning as applied to pitching is similar to that set forth for rolling, except that the motion is longitudinal instead of lateral. In this case, the disturbing moment is greater in an airship, owing to its greater length; the correction is similarly made in both cases and is largely manual. Owing to the distribution of weight along the keel, however, the moment of inertia of an airship is very great, so that the pitching motion is a slow one. In the case of the airplane, owing to the concentration of weight near the center of gravity, the motion is short, which renders it more unpleasant from the point of view of passengers.

Vertical Bodily Displacement

Bodily displacement of an aircraft vertically may take place when air forces act on the whole craft rather than on a part, as in the cases previously considered. In ships of similar gross-weight, totally immersed in a vertical current, similar motion might be expected. In practice, however, the airship scores for two reasons: first, because of its greater length, it will take a disturbance of greater area to immerse it totally; and, secondly, its gross weight, hence its inertia, will also be greater.

The chief source of vibration is the engines, and the discomfort caused by them is dependent largely on the distance of their installation. In an airplane, the space for passengers must of necessity be in fairly close proximity to the engines; hence, the vibration may be severe. In an airship, to place the passengers at a considerable distance, so that the effect of vibration can be practically eliminated is possible.

The magnitude of this superiority in comfort is so great that it is safe to say that, when considerations of cost allow the operation of airships, passengers will refuse to travel on competing airplanes except in cases of emergency.

Similar Characteristics

The conclusions reached from considerations of aerodynamic efficiency, size and comfort are subject to modification by additional factors, of which the most important are (*a*) initial percentage of useful load, (*b*) initial cost per unit of gross weight, (*c*) relative operating-costs, (*d*) insurance and safety, and (*e*) rate of depreciation. At present, to prove that an appreciable advantage exists in favor of either type of aircraft is not possible, yet such an advantage may appear as information and experience accumulate, and may cause us to modify considerably the conclusions that now seem sound. If, for example, the risk attached to travel by airship should ultimately prove to be appreciably greater than that by airplane, considerations of comfort would become of secondary importance. Similarly, the aerodynamic advantage in favor of the airship, which really means lower running-expense and a larger percentage of useful load over long distances, may be negatived by adverse differences in any of the factors in this group. Any of the last four, which affect the cost of operation, can wipe out an advantage in the matter of fuel consumption, while an advantage in the initial percentage of useful load would definitely give the short-range field to the airplane.

Initial Percentage of Useful Load

For our present purpose, the initial percentage of useful load can be taken to mean the percentage of gross lift available for paying load, fuel, passenger accommodations or cargo racks, and fuel tanks. In the case of the airplane, it is gross lift less the weight of the structure, powerplant, instruments, and crew; in the airship, ballast also must be deducted.

It is difficult to find a fair basis of comparison for gross lift. In an airplane, it is dependent on the wing-loading; in an airship, on the purity of the lifting-gas. In the latter case, 68 lb. per 1000 cu. ft. is generally accepted in America and England; in the former, no standard exists, although it usually approximates 9 lb. per sq. ft. of wing surface. Even in the airship, 68 lb. is by no means an absolute figure. It might be exceeded in an airship in continuous operation using pure hydrogen and continually purging, either by valving or burning. On the other hand, if helium is used instead of hydrogen, the figure is approximately 8 per cent less.

An airship, in the matter of structural dead-weight, possesses an apparent advantage of slightly more than 10 per cent of the gross lift; certain corrections must be made, however, that place the two types on an approximate equality. Airplanes have staggered off the ground so heavily loaded that the dead-weight represented just 50 per cent of the gross load lifted; in some of the last of the war-time Zeppelins, the dead-weight was less than 40 per cent of the total.

Percentage of Dead-Weight to Gross Load

In a properly equipped airplane ready for regular service, the dead-weight is likely to be between 60 and 63 per cent of the gross load, while in an airship under similar conditions it will probably be 50 per cent. The above percentages for the airship have been estimated on the basis of 100-per cent inflation at sea-level. This is an ideal condition; in practice, a safe elevation must be attained immediately after taking the air, and emergency ballast must also be carried. The first condition will probably call for a height of 2000 ft., involving, with 100-per cent inflation, the dropping of 6 per cent of ballast, or the gas cells can be inflated to 94-per cent fullness only, so that the desired height can be attained without loss of gas. In addition to this deduction of 6 per cent, a certain reserve-buoyancy must be available for emergencies or for trimming the ship preparatory to landing. For this purpose, water ballast is carried, and 5 per cent can be accepted as a fair figure for the amount necessary on the basis of present practice. This 11 per cent must, of course, be deducted from the useful load, which thus, for both types, becomes 40 per cent, or slightly less.

Reserve buoyancy cannot be dispensed with; but sacrificing useful load to obtain it should not always be necessary. By the use of water-recovery apparatus, ballast can be manufactured en route and thus be available at the time that it is usually needed, that is, at the end of the flight. Should an emergency arise early in the course of a flight, it can be taken care of by dropping fuel. "Slip tanks" are provided, in any case, to enable this to be done. The quantity of water necessary to be carried at the start is thus materially reduced. Although probably no advantage is realized in inflating

beyond 97 per cent, to do so and to attain an elevation in excess of 1000 ft. by dynamic means, thus taking-off with the maximum of useful load and sacrificing a little lifting-gas to attain extra altitude is entirely pos-. sible. The deductions under the head of ballast may thus be distinctly less than the 11 per cent here conceded. In fairness to heavier-than-air craft, it might be pointed out that the large metal flying-boat type may also be able to surpass the common figure of 40-per cent useful load. Some recent designs, notably the PN-9, have carried 50-per cent and, although these performances have been of the nature of stunts, the type may still have a very high percentage of useful load available for normal operation.

Initial Cost

In initial cost per unit of gross weight, at first sight the airplane would seem to possess an overwhelming advantage, but this is not the case. No figures are available, unfortunately, on American costs, but such figures have been published in England, and the cost of construction there, for both types, seems to be about $10,000 per ton. Official estimates, in 1921, showed the cost of commercial craft weighing between 3 and 6 tons to lie between £6,000 and £12,000, or approximately £2,000 per gross ton. This has been checked by an estimate made by J. D. North,[4] an authority on metal construction, who places the cost of the structure at 15 s. per lb. of gross weight, plus the cost of the equipment for passengers, plus £4 per hp. for the powerplant. This works out at approximately £2,250 per ton, plus the cost of equipment.

In the cast of an airship, it is understood that the contract price for the 5,000,000-cu. ft. ship now being built by the Airship Guarantee Co. is £300,000, or £2,000 per gross ton. As the first of a type is of necessity more costly than later ships of the same or similar design, this figure should be lowered in the future, so that the unit cost of airship construction, in spite of the great size of the craft, should not exceed that of the airplane.

The above figure for unit cost of airship construction has been checked by the sum paid to the Zeppelin Company by the German Government for the construction of the ZR-3. The price paid was $750,000, which again works out at $10,000 per ton.

Relative Operating-Costs

To include the item of relative operating costs is necessary, although the information available is too meager to allow any detailed conclusions to be drawn. The use of the mooring-mast overcomes the most serious objection that has been raised against the airship, namely, the ground crew of several hundred men necessary to handle it whenever it comes to earth. The actual flying-crews are dependent on two things, the size of the craft and the number of watches that must be kept. An airship of the size of the Los Angeles usually carries a crew of about 30 men, comprising, in addition to the captain, a double watch composed of a navigator, a watch officer and 2 helmsmen, a keel officer and 2 riggers, an engineer officer and 5 engineers, and a radio operator. In addition, an aerologist and cook may be carried and, when passengers are transported, stewards are needed to provide the necessary service. Although such a crew would probably suffice for an airship of 150 tons, it is likely that, for such ships making long flights on a regular schedule, three watches would be needed, so that the crew would amount to 45 or 50 men. On this basis, one member of the crew is needed for each 3 tons of the airship. In the case of the airplane, one pilot is adequate for craft up to 3 tons gross weight on short flights. For larger craft and for longer flights, a larger crew is necessary. The PN-9, for example, having a gross weight of 9 tons, on her attempted flight to Hawaii carried a crew of 5 men whose duties were those of pilot, assistant pilot, navigator, radio operator, and mechanic. This, of course, was a flight of unusual duration but on large craft even on short flights the regular duties are more than one man can reasonably handle. It would not seem unreasonable, therefore, to estimate one member of the crew for each 3 tons of the craft in this case, also, so that the unit cost of the crew will be equal for both types, except for airplanes of less than 3-ton capacity, in which a single pilot will represent a greater relative charge.

Insurance and Safety

The highest possible degree of safety is necessary in aircraft for two reasons: first, in freight machines, if the risk is too great, the insurance rates will be too high; and, secondly, in passenger machines, if the passengers feel that any real danger of loss of life exists, they will refuse to travel, whatever the other advantages may be. Very little real information is available at present, but a brief discussion of some of the main conditions affecting safety may tend to show that an airship is not so dangerous as is popularly supposed.

The first, and in the popular mind the greatest, risk is that of fire, the cases of the ZR-2 and the Roma immediately coming to mind to create an impression unfavorable to the airship. That structural failure was the primary cause of both these disasters, and that the fire followed, should be remembered, however. When serious accidents have occurred to airplanes, fire has also occurred in a large percentage of cases. The greatest danger of fire lies not in the hydrogen of the airship, but in the highly inflammable liquid-fuel.

In this respect, both types are in similar positions, as ignition of the gasoline in all probability would mean destruction of the craft. Ultimately, heavy oil probably will be used for fuel and the dangers from this source will be eliminated. When helium is used, even the secondary danger of fire in the lifting-gas is avoided. In spite of the present tendency to discredit hydrogen, I believe that hydrogen will ultimately be used successfully and safely in this Country. Even with present methods, if proper care is taken, for example, to keep below the pressure-height in the vicinity of a thunderstorm, the risk is not serious. By insulating the hydrogen with cooled exhaust-gas, a measure of safety can be attained that is not far short of that inherent in helium.

Storms involve risk to life and property wherever they are encountered, the air being no exception. If it is of sufficient violence, an air disturbance conceivably could cause the actual destruction of either an airship or an airplane in the air, the risk being greater for the airship owing to the huge surface exposed to the effect of gusts. Such a possibility, however, is exceedingly remote. With proper meteorological information and with the aid of radio, an aircraft should usually be able to avoid a storm by running away, since the dangerous periods of storms are usually of short duration, and the speed of the craft exceeds the movement of the storm.

The Shenandoah

The loss of the Shenandoah does not prove the frailty of the airship but tends to emphasize the above state-

[4] See the *Journal of the Royal Aeronautical Society*, April, 1924, p. 229.

ments. In the first place, she was too slow a ship to be operating deliberately in a thunderstorm area when such storms might be expected. The maximum speed of the 150-ton ships contemplated today will be not less than 80 m.p.h. which is about 25 m.p.h. more than that of the Shenandoah. Had the Shenandoah possessed such speed, without any doubt she would have been able to avoid the storm by which she was wrecked. Secondly, she received no local weather information. Such information will undoubtedly become available as air traffic expands and will help aircraft to avoid local danger-areas. Thirdly, although it is admitted that a severe storm alone could have broken her in the air, the evidence seems to indicate that she withstood an initial buffeting of great severity and that excessive pressure in the gas cells combined with the storm stresses brought about her ultimate destruction. Her valve system at the time of the disaster was such that she undoubtedly would have been destroyed by gas pressure alone had she met conditions distinctly less severe than the worst experienced by German Zeppelins.

That statement calls for some explanation; so, perhaps, I may be permitted to diverge from my subject for a moment to describe the changes that were made in the valves and the effect of these changes on the operation of the ship.

Usual Procedure

The usual procedure on rigid airships has been to provide every cell with an automatic valve, so that, no matter what happened, gas could always escape rapidly enough to avoid the bursting of a cell during a rapid ascent. Each cell was entirely independent of other cells. Recently, however, to carry a gassing manifold within the keel, has been found desirable. This manifold consists of a fabric tube running the whole length of the ship and having a branch pipe attached to each gas cell. This collapses when not filled with gas and can be closed at any point by simply tying it off with a cord. The convenience of this system will be readily appreciated, for it greatly simplifies the gassing operation, especially when this is done with the airship attached to a mooring-mast.

In the Shenandoah, this manifold was made to serve an additional purpose. Those concerned believed that they could save weight by removing the automatic valves from the cells having maneuvering valves, providing these cells with a connection by way of the manifold to a cell with an automatic valve, and relying on the automatic valve and the manual valve for the discharge of gas when crossing the pressure-height.

At first sight, this scheme may appear attractive. The cell with the automatic valve is unchanged; that without it has a maneuvering valve of adequate area and, in addition, has an opening to a cell with an automatic valve so that, should the maneuvering valve fail to function, gas can still escape. This reasoning, however, is superficial.

Purpose of Automatic Valves

The purpose of an automatic valve is to function in an emergency without attention. Even with the most skilled operation conceivable, the opening of all the valves could not always be relied upon with certainty. In an emergency, the man whose duty it is to see to the valves might be stricken; his attention might be distracted by closer emergencies; in his haste he might omit to pull one valve; or he might fail to open the valves wide enough. In addition, and in spite of the most careful inspection, mechanical failure might occur in the long line from the control-car to the valve on the top of the ship, or the valve itself might stick.

In a valve system such as that of the Shenandoah, the possibility of the failure of a maneuvering valve to open must therefore be faced; and it must be remembered that the safety of the ship would then depend on the adequacy of the remaining provisions to allow the escape of gas fast enough.

Gas Pressure

Let us therefore consider the gas pressures that would be produced automatically in the cells of the Shenandoah, if the valves were arranged as on the last flight, and compare them with the pressures that would occur under similar conditions in cells having the usual valve arrangements.

The gas from two cells must now flow through a valve that formerly handled the volume of gas from one cell only. The velocity through the valve-opening is therefore twice its former value; and the pressure necessary to discharge the gas at this velocity is four times as great. This is not all, however. It applies to the cell with the automatic valve; the other cell has a pressure greatly in excess of this, for it must force its gas through the opening into the manifold, through a considerable length of manifold and around two sharp bends. The area of the manifold is less than that of the opening of the automatic valve, so that the gas must flow at a velocity in excess of the maximum that could occur through the valve under the old system. When the resistance of the manifold and of the bends is added, the pressure above that of the first cell which is necessary to get the gas out of the second, becomes at least twice, and probably three times, the originally designed figure. The pressure in the cell without an automatic valve is therefore between six and seven times its original maximum.

Hydrogen Versus Helium

But this is not all. The valves of the Shenandoah were similar to those used in the L-49 and other German Zeppelins, and were designed for ships of that type, which were inflated with hydrogen. As is well known, the Shenandoah was inflated with helium, a denser gas than hydrogen. This increase in density would cause an increase of 50 per cent in all the pressures that have been mentioned. German experience indicates that valves of the type originally on the Shenandoah were just adequate to meet the worst conditions actually encountered. With possible pressures 10 times as great as the worst experienced in German practice, pressures undoubtedly far in excess of the breaking-load, anything might happen in an emergency.

The automatic valves alone being inadequate to prevent the bursting of a cell, the conditions can be compared to those of a steam-boiler, the safety of which against an explosion is dependent on the opening of a hand-valve by an operator shortly before the explosion is expected.

The relative responsibility of the valves and of the storm for the loss of the Shenandoah will probably never be determined, but under such conditions to lay the blame on the craft is hardly fair.

Errors of judgment, even with the most skilled personnel, are likely to occur occasionally. The likelihood of these being of serious consequence is greater with an airplane, when the time available for correction is generally very short; in an airship, an error is less likely to occur, since, in an emergency, a decision need be made

less hastily, and for the same reason can be more readily corrected.

An error, even of omission, in an airplane may result in complete loss of equilibrium with possibly very serious consequences, whereas in an airship steady flight will be departed from gradually and the consequences come into effect relatively slowly.

Dangers of Landing

One of the greatest risks to aircraft lies in making a landing. If it were necessary to house an airship in its shed at the termination of every flight, and at the same time to maintain a regular schedule, the risk of damage due to its being caught in eddies and gusts would, no doubt, be appreciable; but when the ship need return to its hangar only for overhauling or repair and can, within limits, choose its own time for doing so, making its regular stops at a mooring-mast to main a regular schedule without much risk in making connection with the earth should be possible.

The risk of damage arises from direct contact between the moving aircraft and a fixed object, and the resulting damage is dependent primarily upon the momentum with which this contact is effected. In spite of its great mass, an airship can usually approach the ground at a very low velocity. On the other hand, an airplane must make contact at a relatively high-speed and, if anything should go wrong, the consequences are more serious.

In the case of passengers, the risk of injury depends on the velocity of the aircraft at the time of impact. Serious injury may occur if this velocity exceeds about 20 m.p.h. It is obvious that this risk is present in an airplane but is negligible in an airship.

Engine Stoppage

Engine stoppage is the direct cause of much of the trouble that aircraft may encounter and may arise from either mechanical breakdown or exhaustion of the fuel supply. In an airplane, either cause will involve a forced-landing, and this is always accompanied by a risk of appreciable magnitude. In an airship, no immediate danger exists; the powerplant is split into three or more units, and one-half of them may fail, yet the journey can still be completed in little more than the scheduled time; even though all but one should fail, a base can be reached at reduced speed. Furthermore, the engines are accessible and, except in the case of really serious breakdowns, repairs can usually be made in the air.

Even exhaustion of the fuel supply does not place an airship in immediate danger, since it can remain in the air and "free balloon" for at least 24 hr. It cannot remain up indefinitely, owing to variations of temperature that require either the discharge of ballast or the valving of gas. The variations that cause trouble are those between the air and the lifting-gas, namely, superheating, which may easily cause an excess lift amounting to 5 per cent of the gross lift of the ship. In an airship, the engines of which have stopped, this would involve a rise to pressure height and a discharge of gas through the automatic valves. When the gas began to cool at a greater rate than the air, ballast would have to be discharged. Enough water is normally carried to enable an airship to remain out 1 night, but whether it could endure a second is doubtful. In this respect, a prospect of even greater safety in the use of water recovery exists, for, with all the fuel gone, an equivalent weight of water would be available, which should outlast some four or five nights. If an emergency arose, for example, through being blown off the course by a storm near the end of a flight, an airship captain, assured of enough reserve buoyancy to outlast several nights, could conserve his remaining fuel, and free balloon until the storm abated. With services in regular operation, enough bases or masts should be in existence for him to reach one in safety at reduced speed after the abatement of the storm, and he could then refuel and resume his voyage. Whatever the exact measures adopted, the ability to remain in the air without danger for so long a period would give the captain much greater freedom in meeting an emergency.

Depreciation

No satisfactory data on depreciation are yet available, nor can they be expected until an appreciable number of aircraft of both types have actually been worn out in service. The most perishable item, the fabric outer-covering, is subject to a similar deterioration in both types. The main structural members, so far as can be seen at present, are in a similar position. In its gas cells the airship possesses a perishable item not shared by the airplane. The life of these is possibly twice that of the outer covering and one-third that of the hull. So long as goldbeaters' skin is necessary to make the fabric gas-tight, they will, no doubt, be expensive. However, that a substitute for this material will ultimately be found seems probable.

This disadvantage of the airship should be offset by the greater durability of its engines. In an airplane, the engine is normally called upon to operate for short periods at full power and for fairly long periods at a relatively high output; in an airship, full power is very rarely called for and the usual operating-speeds represent a relatively small load. A given engine could be expected to last longer, therefore, in an airship. At present, airship engines are built heavier, and for this reason are more durable. This advantage, however, is not likely to be permanent, since, with less exacting requirements, to save weight by using engines no heavier than those which are satisfactory in an airplane, where the utmost in reliability is required, would pay.

Conclusion

In conclusion, on account of its aerodynamic superiority, that the airship will be used wherever possible for carrying passengers in comfort, appears probable. However, a very large field exists in which it cannot be used, since the load will be insufficient to fill it reasonably. The factor determining the choice of type is size, for the range and the speed are incidental That the airship will continue to be a long-range and the airplane a short-range vessel, is probable, however, with the exceptions that the airship may be used on comparatively short routes at night and when the traffic attains considerable volume, and that the airplane may encroach on the long-range field when the density of traffic is low, especially when existing communication is poor and a fairly high price may be demanded for the service.

Although the cost per ton-mile of transportation by airplane will be greater than by airship, this does not imply any serious limitation to the use of the airplane within its own field. Somewhat similar conditions exist with surface transportation, in which the costs by water and by rail, roughly, are in the ratio of 1 to 10. In spite of a tenfold inferiority, the railroad is used because it is needed in a field in which the cheaper form of transportation is unable to operate. No reason to suppose that the relative magnitudes of heavier-than-air and lighter-than-air operation will not be in a ratio similar to that between rail and water transportation exists.

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Supercharging Internal-Combustion Engines

By C. R. SHORT[1]

ANNUAL MEETING PAPER *Illustrated with* DRAWINGS

ABSTRACT

WITHOUT attempting a scientific discussion of supercharging, the paper presents historical data concerning engines in which the supercharging principle has been employed, such engines being those which utilize special means whereby the cylinder charge is increased beyond the normal charge obtained by filling the cylinder at atmospheric pressure. The object of supercharging is to obtain a greater output of horsepower, due to the greater quantity of fuel mixture consumed and the resulting additional heat-units set free during combustion.

The piston-pump, the vane-pump, Roots blower, and the turbo-compressor are the four types of pump used to supply the required quantity of gas-and-air mixture, a pump of some suitable design being an essential feature. Supercharging methods are outlined, including forced and supplemented induction, scavenging and the use of the two-stroke cycle.

With respect to the different methods used in supercharging different designs are illustrated and their special features are explained. The historical data presented include stationary as well as automotive engines and show that supercharging in some form or other has been employed as far back as the gas engine can be traced. Aircraft, Diesel and racing engines are considered, as well as those for passenger cars.

Regarding supercharger development for passenger-car engines, the author suggests the possibility of designing a supercharger that will produce greater torque at low speed and enumerates some of the advantages that would result if this were accomplished.

A BRIEF history is presented of engines in which the principle of supercharging has been employed. The data collected have been obtained from the library of the General Motors Corporation Research Laboratories and from that of the city of Detroit. No scientific discussion of the principle of supercharging is attempted, the paper being limited chiefly to the different methods of supercharging, the various designs of supercharger and the different engines that employ this principle. A definition of the term "supercharging" as it is understood in this paper is as follows: If we understand by a cylinder charge that quantity of fuel and air, by weight, necessary for its efficient combustion, normally drawn into the cylinder previous to combustion, then we can define as being "supercharged" such engines in which the cylinder charge is increased by special means above the normal charge obtained by filling the cylinder at atmospheric pressure.

The object of supercharging is to inject a greater quantity of fuel mixture into the cylinder per filling than normally would be possible and, from the resulting additional heat-units set free during combustion, to obtain a greater output of horsepower. To supply the required quantity of gas-and-air mixture at the desired pressure, a pump of some suitable design must be provided. Four types of pump have been used, these being the piston-pump, the vane-pump, Roots blower, and the turbo-compressor. In cases in which the engine weight must be kept low, as in airplane and automobile engines, a piston-pump is out of the question. The other three types must therefore be resorted to.

GENERAL TYPES OF SUPERCHARGER

The various methods used for supercharging an engine can be classified as being those of forced and supplemented induction, scavenging and use of the two-stroke cycle. In the forced-induction engine, the whole of the charge is supplied to the cylinder at a pressure higher than atmospheric, the normal suction of the engine not being utilized. The total charge is supplied to the engine by a special pump and sometimes a receiver is interposed between the pump and the cylinder from which the latter can obtain its charge. In this manner the engine is entirely independent from the condition of the air surrounding it and will operate as if it were surrounded by a denser atmosphere.

As to the supplemented-induction supercharged-engine, to reduce the pumping work and size of the pump the normal suction of the engine can be utilized to furnish the greater quantity of the mixture of gas and air, supplementing this charge by special means. The size of the pump will be considerably smaller and the weight of the powerplant will not be affected materially. The one drawback in this method is the complicacy of the valve mechanism and timing required.

The principle of the scavenging engine consists in employing a pump that will furnish a volume of air at a pressure slightly above atmospheric. This air is used to free the combustion-chamber or cylinder of the residue of exhaust gases, leaving the cylinder filled with pure air of a somewhat higher pressure. The greater proportion of oxygen contained in this air permits the use of a richer mixture, in this manner increasing the output of the engine. In reality, therefore, it does not supply a greater charge, or does not supercharge in the strict sense of the word, but it clears the cylinder of the hot gases, cooling at the same time the cylinder-walls and the exhaust-valves. By these means it is possible to raise the compression-pressure above that which would be used normally. This fact, together with the lower temperatures employed in the cycle, assure a higher thermal-efficiency.

In considering the proposition of a two-stroke supercharged-engine, particularly the one using positively operated valves, the question of supercharging resolves itself into determining the dimensions of the pump necessary to supply the charge. In the case of the two-stroke engine the charging pump is a necessity, and it would require only a slight increase in the weight of the engine

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to increase the size of the pump to dimensions able to furnish the quantity of the mixture necessary for supercharging. This method has been used very effectively in the design of large Diesel engines. In the case of the gasoline engine, the one great drawback is the wastage of fuel pushed out through the exhaust-ports during the scavenging process, unless pure air is used for this process and the fuel injected later. This method, of course, involves further complications due to the use of special delicate fuel-valves, pump mechanism and the like, besides adding to the weight of the engine. The first design of the two-stroke engine utilized the crankcase compression as the scavenging means. One designer, recognizing the waste of fuel during the scavenging process, has employed the method of clearing the exhaust gases out of the cylinders by the crankcase compression and uses an additional pump to furnish the supercharge of fuel and air.

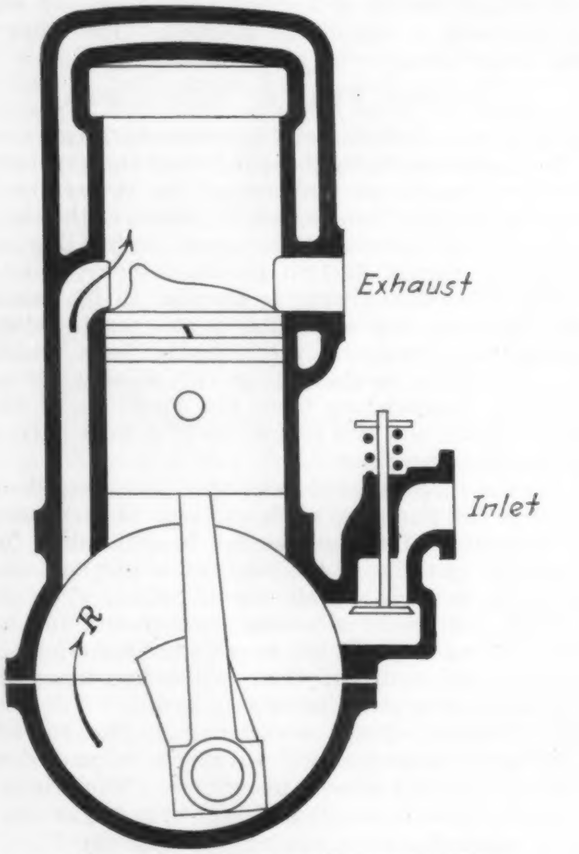

FIG. 1—DAY TWO-CYCLE ENGINE OF 1891
This Was Designed for Supercharging by Crankcase Compression and Required only an Appropriate Dimensioning of the Crankcase Chamber To Obtain also a Supercharging Effect

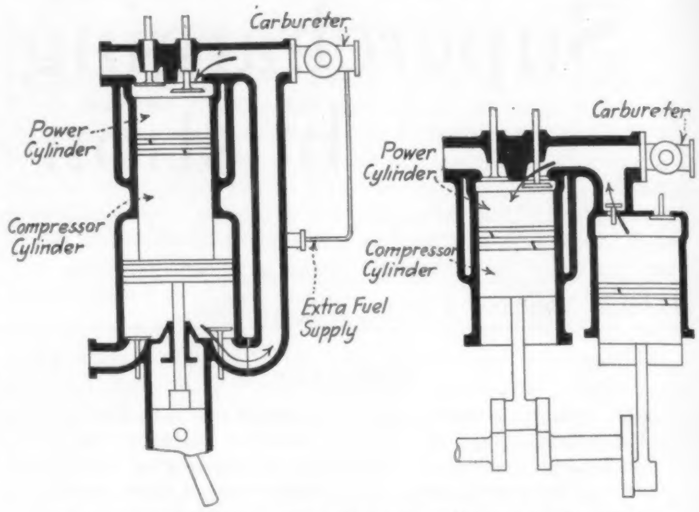

FIG. 2—COMBINED AND SEPARATED COMPRESSOR-PISTONS
At the Left, a Large Piston Is Added As an Extension to the Power Piston To Act As a Compressor Piston. The Down Stroke of This Piston Compresses the Air in the Lower Cylinder, Which Is Controlled by Valves, and Forces It at a Certain Predetermined Time and Pressure through the Transfer Passage into the Power Cylinder. By Choos.ng Appropriate Dimensions for This Compressor Piston and Cylinder, Any Degree of Supercharging Can Be Obtained. The Wittig & Hess Engine of 1878, Shown at the Right, Is the Same in Principle but the Pistons and Their Cylinders Are Separate Units

With respect to the different methods used in supercharging, the engines can be grouped into classes in which supercharging is accomplished by (*a*) crankcase compression, (*b*) by a special piston-pump, (*c*) by a vane-pump, (*d*) by a Roots blower, and (*e*) by a turbocompressor.

Fig. 1 is a sketch of a design for supercharging by crankcase compression. This type has been used extensively in two-cycle engines in which scavenging is a necessity. As already explained in the case of the piston compressor and scavenging pump, it requires only an appropriate dimensioning of the crankcase chamber to obtain also a supercharging effect in this case.

Fig. 2 shows at the left a design in which a large piston is added as an extension to the power piston, to act as a compressor piston. The down stroke of this piston compresses the air in the lower cylinder, which is controlled by valves, and forces it at a certain predetermined time and pressure through the transfer passage into the power cylinder. By choosing appropriate dimensions for this compressor piston and cylinder, any degree of supercharging can be obtained. The drawing at the right in Fig. 2 shows a design in which both pistons and cylinders are separate units. In every other respect, this arrangement is the same as that shown in the other half of this illustration.

At the left in Fig. 3 is a diagrammatic sketch of the

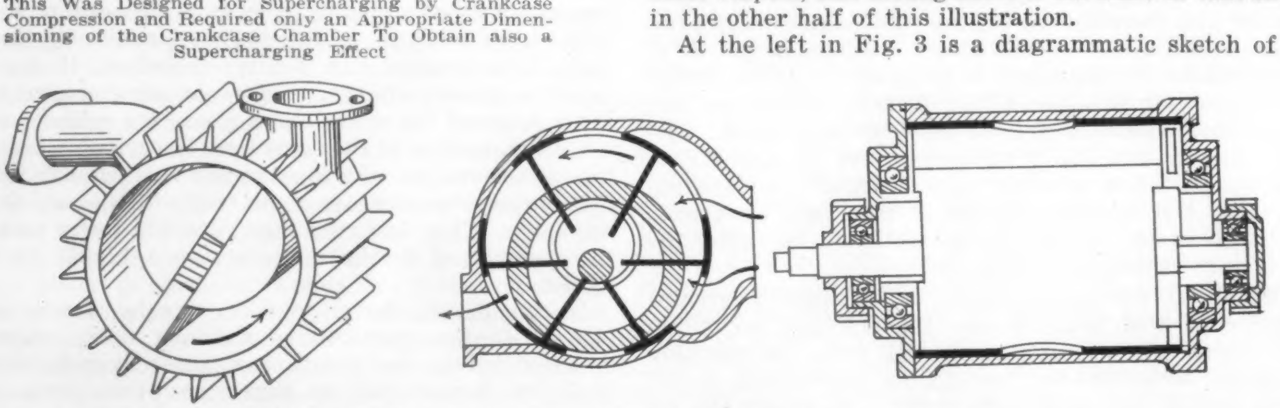

FIG. 3—VANE-PUMP SUPERCHARGERS BY ZOLLER AND BY COZETTE
At the Left, the Vane-Pump Supercharger Designed by A. Zoller Has a Number of Vanes Which Rotate in a Cylinder about an Eccentric Hub, in This Manner Decreasing the Volume Existing between Two Successive Vanes and Compressing the Charge. The Design Shown in the Central and Right Views, by R. Cozette, Utilizes the Same Principle

vane-pump supercharger as designed by A. Zoller. A number of vanes rotate in a cylinder about an eccentric hub, in this manner decreasing the volume existing between two successive vanes and compressing the charge. The center and right drawings show a later design by R. Cozette employing the same principle, which was tried out in 1925 in French racing cars.

Fig. 4 shows, at the left, a front view of a Roots blower with two blades which has been used successfully for several years by engineers of the Mercedes Company. They have adopted it for standard production in the latest model of passenger cars of this firm. Besides Mercedes racing cars, Vauxhall, Talbot, Sunbeam, Alfa-Romeo, and others have used it successfully in their racing cars.

The Roots blower consists of a casing, provided with a number of ribs for cooling purposes, in which two blades of the shape shown revolve. The shafts of these blades rotate in opposite directions. The impellers scoop-up the air that enters through the inlet-ports, and force it through the outlet-port into the cylinders. The Roots blower, therefore, acts as a gear-pump and can develop a definite pressure in the inlet-manifold of the cylinders. The pressure generally used varies between 4 and 5 lb. per sq. in. The left central view in Fig. 4 shows a modification of the Roots blower that employs triple blades. This Berk supercharger, as it is called, has been tried out and will be standard equipment for the following English cars: A. C., Austin-Seven, Alvin, Aston-Martin, and others. It is built by Thwaites Bros., Bradford, England, and differs from the ordinary Roots blower in having three blades, in this manner approaching more nearly the ordinary gear-pump. It is claimed that the air current furnished by this supercharger is more constant, and that it is not necessary to have an accurate adjustment of the blower with respect to timing, as is the case with the Roots blower. A view of the impeller and an exterior view of the complete unit are presented in the right half of Fig. 4.

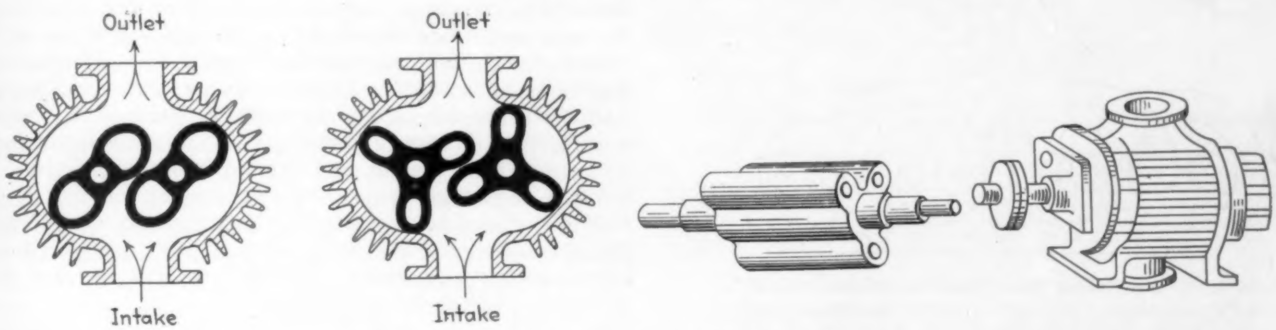

FIG. 4—ROOTS BLOWER AND BERK SUPERCHARGER
The Roots Blower Shown at the Extreme Left Consists of a Casing Provided with a Number of Ribs for Cooling Purposes in Which Two Blades of the Shape Shown Revolve. The Shafts of These Blades Rotate in Opposite Directions. The Impellers Scoop-Up the Air That Enters through the Inlet Ports and Force It through the Outlet Port into the Cylinders. The Blower Therefore Acts as a Gear-Pump and Can Develop a Definite Pressure in the Inlet-Manifold. The Berk Supercharger Shown in the Left Central View Is a Modification of the Roots Blower That Utilizes Triple Blades. It Will Be Installed as Standard Equipment on Several Makes of English Car. A View of the Impeller and an Exterior View of the Complete Unit Are Presented in the Right Half of This Illustration

The drawing at the extreme left of Fig. 5 is a sketch of the turbo-compressor and gas turbine developed by Professor Rateau in France and Dr. S. A. Moss, of the General Electric Co., in America. Both use the exhaust gas of the engine for driving a gas turbine which, in turn, drives a centrifugal or turbo-compressor. The development of the turbo-compressor of Dr. Moss has been made at McCook Field, Dayton, Ohio. The left central drawing shows a section through the housing of the Rateau supercharger. The other three drawings of the illustration picture the diffusor, rotor and general aspect of the Schwade supercharger that had been developed in Germany toward the end of the war for use in airplanes. It is of the turbo-compressor type, built in three stages. Both the B. M. W. and the Maybach engines were equipped with this type of supercharger, as well as the rotary engines. It was gear-driven and, being connected with the engine by an automatic clutch, it started to operate as soon as the speed of the engine reached 600 r.p.m.

Perhaps the earliest attempt to supercharge an engine cylinder of a motor vehicle can be found many years ago when the early racing drivers fitted a funnel, similar to the kind used in phonographs and facing forward, to the air-intake of the carbureter. The idea was that, at high speed, the air passing the car would be collected

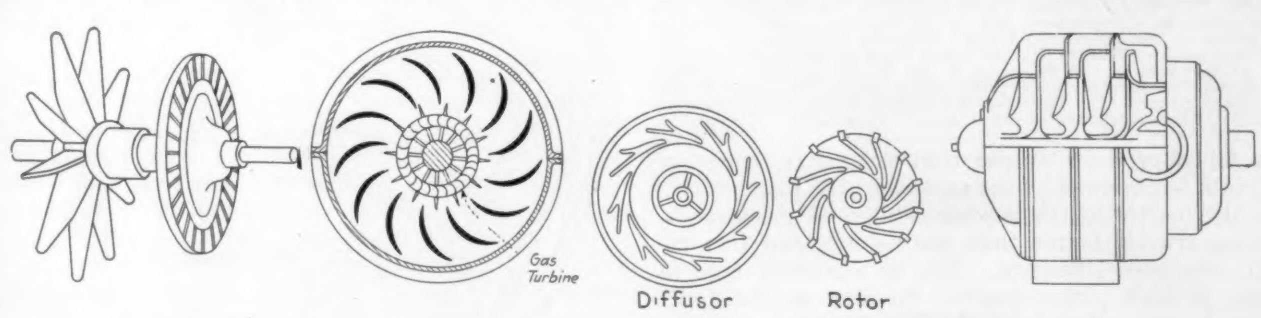

FIG. 5—TURBO-COMPRESSOR AND GAS TURBINE AND THE SCHWADE ROTOR AND DIFFUSOR
The Turbo-Compressor and Gas Turbine Developed by Dr. S. A. Moss in America and Professor Rateau in France in Which the Exhaust Gas of the Engine Is Used To Drive a Gas Turbine That, in Turn, Drives a Centrifugal or Turbo-Compressor, Is Shown at the Extreme Left. The Left Central View Illustrates the Rateau Supercharger, Being a Section Taken Through the Housing. In the Remaining Drawings the Diffusor, Rotor and General Aspect of the Schwade Supercharger, Which Was Developed for Use in Airplanes, Are Shown. It Is of the Turbo-Compressor Type and Is Built in Three Stages

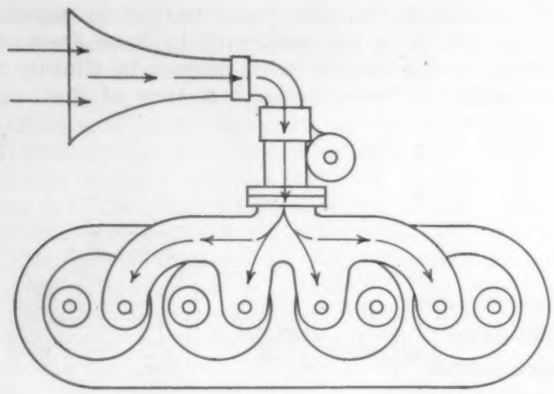

FIG. 6—AIR-SCOOP FIRST USED ON RACING CARS
A Funnel, Similar to a Phonograph Amplifying Horn and Facing Forward Was Fitted by Some of the Early Racing Drivers to the Air-Intake of the Carbureter, the Idea Being That, at High Speed, the Air Passing the Car Would Be Collected and That Its Force Would Drive the Mixture into the Cylinder. However, the Advantage Gained Was Very Slight

and would drive the mixture into the cylinder. In practice, however, the advantage gained was very slight and only demonstrated the need for improved methods of supplying the air under pressure to produce a sensible increase in power. Fig. 6 shows the funnel or wind scoop as applied to a four-cylinder engine.

HISTORY OF SUPERCHARGING

The supercharging of engines is by no means to be considered a new idea. It had always been acknowledged

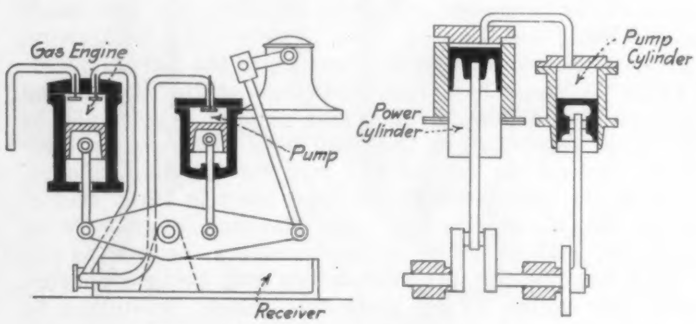

FIG. 7—BRAYTON ENGINE OF 1876 AND SIMON ENGINE OF 1878
The Brayton Engine Shown at the Left Had a Pump and a Power Cylinder, the Pistons of Which Ran in Opposite Directions. The Pump Piston Discharged the Compressed Air into a Receiver at a Pressure of from 60 to 75 Lb. per Sq. In. It Operated on the Two-Cycle Principle, the Inlet-Valve Receiving Its Mixture of Gas and Air from the Compressed Air in the Receiver and Closing at Four-Tenths of the Stroke To Permit Suitable Compression. The Same Principle and Similar Design Were Used in the Simon Engine Shown at the Right; the Power and the Pump Pistons Operated on the Same Crankshaft, the Cranks Being Set at an Angle of 180 Deg. to Each Other. The Receiver Was Omitted, the Two Cylinders Being Connected by a Direct Pipe-Line

that a full charge of 100-per cent volumetric efficiency never could be obtained by the suction of the piston alone. Due to the inertia of the moving column of gas and air, the piston travels faster than the column and this results in decreased efficiency. This is especially true in the case of high piston-speeds. So long as the four-stroke cycle was adhered to, the time for charging was sufficiently great to obtain a reasonable volumetric efficiency, provided the timing was chosen correctly. With the advent of the two-stroke-cycle engine, charging without auxiliary means was an impossibility. Hence, in the earliest designs we find additional compressors in which the charge is compressed before being pushed into the power cylinder. The compression in the crankcase is also utilized for the same purpose. In the two-stroke cycle the removal of the residue of the exhaust gases is also of great importance, so that a scavenging effect by air or by mixture was greatly desired.

When Rudolph Diesel invented his four-stroke-cycle oil-engine in 1893, in which air alone was compressed to 500 lb. per sq. in. before the fuel was injected, it was not thought necessary to use a scavenging or charging pump. As soon as Guldner applied the two-cycle principle to the Diesel engine, both pumps were a necessity. In the first engine, built in 1899 in Augsburg, a two-stage compressor was used, the air of the first stage being used also for scavenging. While the pressure in the scavenging pump was only 75 lb. per sq. in., this pressure was raised for the use of charging to 500 lb. per sq. in. A list of different engines, both stationary and automotive, in which the principle of supercharging has been used, will now be presented and, from this list, it will be seen that

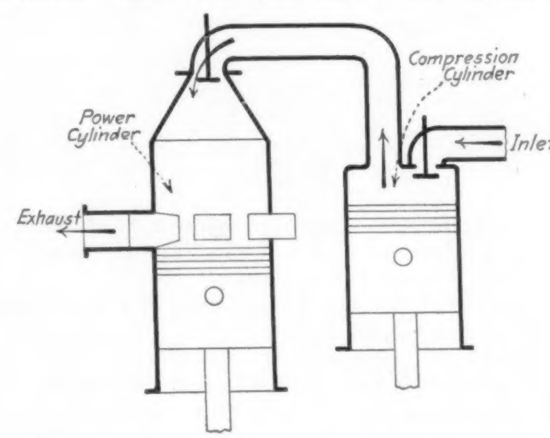

FIG. 8—DOUGALD CLERK TWO-CYCLE ENGINE OF 1878
In This Engine, the Power Cylinder Was Charged by an Adjacent Auxiliary Pump. The Crank of the Pump Was Located at the Flywheel and Set at an Angle of 90 Deg. Ahead of the Power Crank

supercharging in some phase or other has been employed as far back as the history of gas engines can be traced.

ENGINES EMPLOYING SUPERCHARGING PRINCIPLES

The first engine that employed supercharging of which a record can be found is the gasoline engine built by

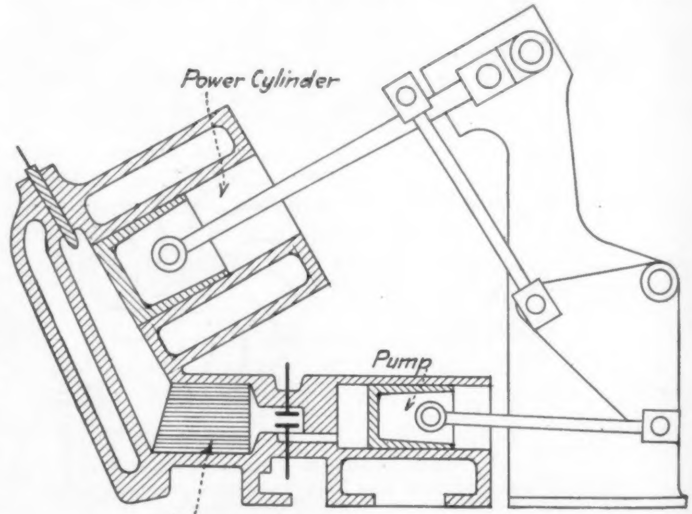

FIG. 9—HARGREAVES ENGINE OF 1890
This Development Resulted from Experiments with Gasoline Engines Equipped with Self-Ignition and Having Water Injection. The Air Was Compressed in a Separate Pump-Cylinder to 75 Lb per Sq. In., Being Heated in a Special Regenerative Chamber. A Small Fuel-Pump Injected a Quantity of Fuel into This Compressed and Heated Air Where It Was Gasified Immediately and Ignited Spontaneously. Therefore, No Ignition Device Was Needed. The Regenerative Chamber Was Heated by the Exhaust Gases

Brayton in 1876. The patents for this engine date back to 1872. It possessed a pump and a power cylinder, the pistons of which ran in opposite directions. A sketch of this engine is shown in Fig. 7, at the left. The pump piston discharged the compressed air into a receiver at a pressure of from 60 to 75 lb. per sq. in. It operated on the two-cycle principle, the inlet-valve receiving its mixture of gas and air from the compressed air in the receiver, and closing at four-tenths of the stroke to permit suitable compression. The same principle and similar design were used in 1878 by Simon & Beachy in Nottingham in their Simon engine. The power and the pump pistons operated on the same crankshaft, the cranks being set at an angle of 180 deg. to each other. The receiver was omitted in this case, the two cylinders being connected by a direct pipe-line. The arrangement of the cylinder was similar in principle to that shown in the drawing at the right.

In the same year, 1878, Dugald Clerk, in England, invented a two-cycle engine in which the power cylinder was charged by an adjacent auxiliary pump. The crank of the pump was located at the flywheel and set at an angle of 90 deg. ahead of the power crank. Fig. 8 is a diagrammatic sketch of this engine.

In the earliest two-cycle gas-engine, built in Germany by Wittig & Hess in 1880, the crank of the charging pump is in line with that of the power cylinder. During the firing stroke of the power cylinder, the pump takes-in air. On the return stroke, the power cylinder pushes

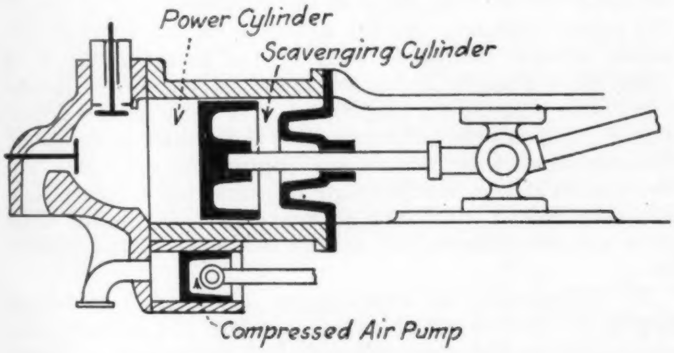

FIG. 10—CAPITAINE ENGINE OF 1891

It Operated on the Two-Cycle Principle, Using the Front End of the Cylinder As a Scavenging Pump. A Small Pump Beneath the Main Cylinder Furnished the Compressed Air Needed for the Injection of the Fuel. After the Compressed Air of the Scavenging Pump Had Driven Out the Exhaust Gases, Both Valves Were Closed and the Air Was Compressed by the Power Piston. At Top Dead-Center, a Mixture of Compressed Air and Gasoline Was Injected into the Cylinder and the Mixture Was Exploded by a Flame

out the exhaust gases for 60 or 70 per cent of the stroke, during which the pump cylinder compresses its charge. At this point the inlet-valve opens, injecting the compressed charge into the power cylinder. During the remainder of the stroke, both cylinders are in communication and compress the charge. At top dead-center, the inlet-valve closes and the charge is exploded.

In 1890, Hargreaves, in England, experimented with gasoline engines having self-ignition and water injection. The air was compressed in a separate pump-cylinder to 75 lb. per sq. in., being heated in a special regenerative chamber. A small fuel-pump injected a quantity of fuel into this compressed and heated air, where it was gasified immediately and ignited spontaneously. Therefore, no ignition device was necessary. The regenerative chamber was heated by the exhaust gases. Fig. 9 shows this engine diagrammatically.

Swidersky, in Leipzig, developed the Capitaine engine in 1891. It operated on the two-cycle principle, using

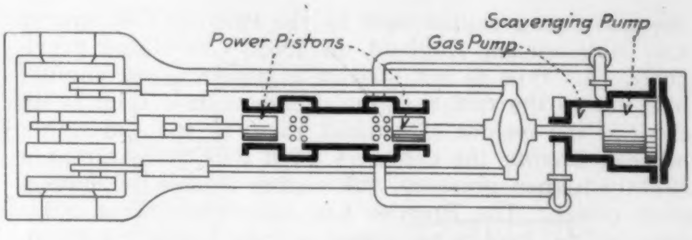

FIG. 11—TWO-CYCLE ENGINE DESIGNED BY OECHELHAUSER & JUNKERS IN 1893

Two Opposed-Pistons Operate in One Cylinder from One Crankshaft. The Push-Rods of the Outer Piston Also Act as Piston-Rods for a Scavenging Pump and a Two-Stage Gas-Pump. The Former Delivers Air under Pressure to the Cylinders, to Which Highly Compressed Gas Is Added near the End of the Power Stroke. The Design Shown Was Made in 1898

the front end of the cylinder as a scavenging pump. A small pump located beneath the main cylinder furnished the compressed air necessary for the injection of the fuel. After the compressed air of the scavenging pump had driven out the exhaust gases, both valves were closed and the air was compressed by the power piston. At top dead-center, a mixture of compressed air and gasoline was injected into the cylinder and the mixture was exploded by a flame. Fig. 10 shows the arrangement used.

In 1893, Oechelhauser & Junkers designed their first two-cycle gas-engine. Two opposed-pistons operate in one cylinder from one crankshaft. The push-rods of the outer piston also act as piston-rods for a scavenging pump and a two-stage gas-pump. The former delivers air under pressure to the cylinders, to which highly compressed gas is added near the end of the power stroke. Fig. 11 shows a modified design made in 1898.

In 1894, Bénier, in Paris, designed the two-cycle engine for power-gas shown in Fig. 12. Bénier also introduced gas and air into the cylinders by separate pumps, using for this purpose a two-stage pump in which the piston of larger diameter pumped the air and the smaller piston pumped the gas.

Korting, in Hanover, Germany, designed this company's double-acting, two-cycle gas-engine for large power-outputs in 1898. A crank, set at an angle of 110 deg. ahead of the main crank, operates both gas and air-pumps. Separate manifolds for air and gas are connected to the inlet-valves, in this manner providing only air for the scavenging process and permitting the gas supply to be added later. Fig. 13 shows the arrangement of this engine.

An example of the scavenging supercharged-engine is

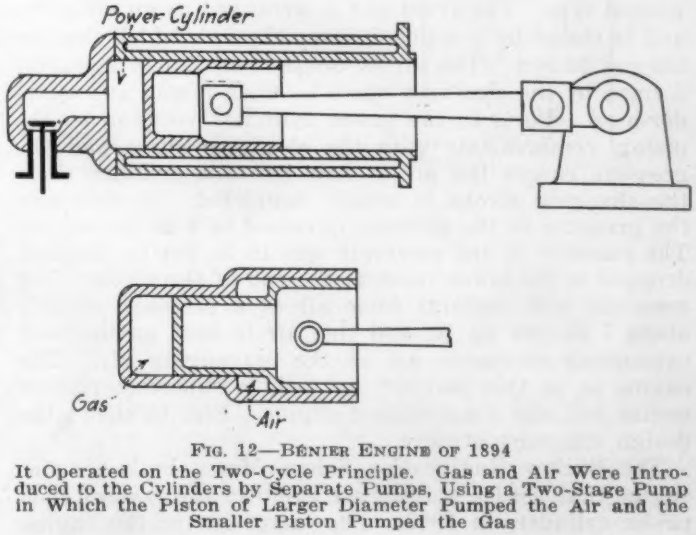

FIG. 12—BÉNIER ENGINE OF 1894

It Operated on the Two-Cycle Principle. Gas and Air Were Introduced to the Cylinders by Separate Pumps, Using a Two-Stage Pump in Which the Piston of Larger Diameter Pumped the Air and the Smaller Piston Pumped the Gas

the scavenging engine built by the Premier Gas Engine Co., Nottingham, England, in 1902. As stated previously, this type is not strictly a supercharged engine; but, due to the fact that the cylinders have been swept clean of the residue of exhaust gases by the scavenging process, leaving the cylinders filled with pure air at a slightly higher pressure, the engine is able to develop more power. The Premier gas engine has three cylinders in-line, two being power cylinders and the third, which is closest to the crankshaft, being the compressor cylinder. The engine operates on the four-cycle principle and, by the use of inlet-valves, the compressor is able to supply both cylinders alternately with scavenging air at a pressure somewhat higher than atmospheric. In Fig. 14, *a* and *b* are the power pistons, *c* is the compressor, *d* is the sliding valve governing the intake to the compressor, and *e* and *f* are inlet valves to the power pistons.

In 1905, the National Gas Engine Co., of Ashton, England, built a gas engine under Dugald Clerk's patents in which a charge of air was injected into the cylinder at a high pressure just before compression began. Fig. 8 shows Dugald Clerk's engine. The power

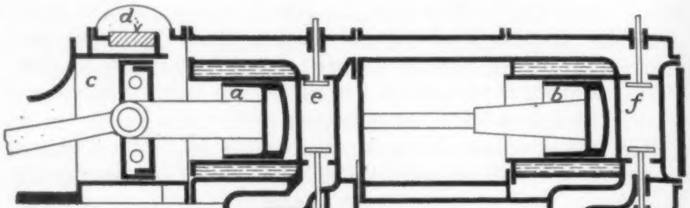

FIG. 14—PREMIER GAS-ENGINE
This Type Is Not Strictly a Supercharged Engine but, Due to the Fact That the Cylinders Have Been Swept Clean of the Residue of Exhaust Gases by the Scavenging Process, Leaving the Cylinders Filled with Pure Air at a Slightly Higher Pressure, the Engine Is Able To Develop More Power. It Has Three Cylinders In-Line, Two Being Power Cylinders and the Third Which Is Closest to the Crankshaft, Being the Compressor Cylinder. The Engine Operates on the Four-Cycle Principle and, by the Use of Inlet-Valves, the Compressor Is Able To Supply Both Cylinders Alternately with Scavenging Air at a Pressure Somewhat Higher Than Atmospheric. In the Illustration *a* and *b* Are the Power Pistons; *c*, the Compressor; *d*, the Sliding Valve Governing the Intake to the Compressor; and *e* and *f* Are Inlet Valves to the Power Pistons

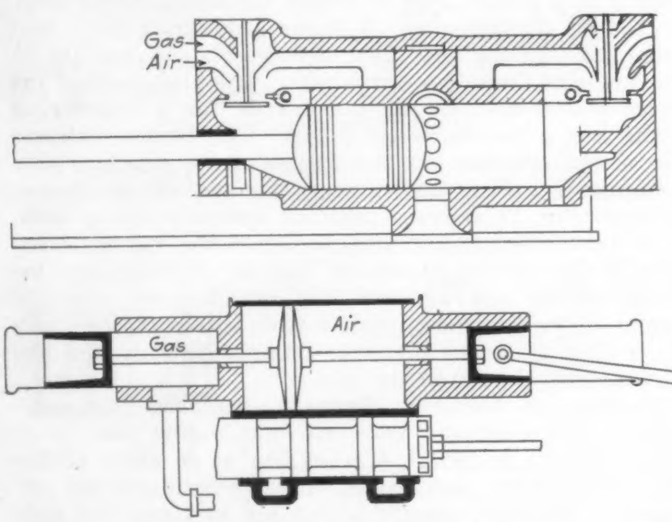

FIG. 13—KORTING TWO-CYCLE ENGINE
It Was Designed for Large Power-Outputs. A Crank, Set at an Angle of 110 Deg. Ahead of the Main Crank, Operates Both Gas and Air Pumps. Separate Manifolds for Air and Gas Are Connected to the Inlet-Valves, in This Manner Providing Only Air for the Scavenging Process and Permitting the Gas Supply To Be Added Later

cylinder, acting on the four-cycle principle, is of the normal type. The front end is arranged as an air-pump and is closed by a cylinder cover through which the piston-rod passes. The air is compressed into a reservoir formed by the clearance space between piston and cylinder-head. Ports in the power cylinder, over-run by the piston, communicate with the clearance space and the pressure causes the air to flow into the cylinder when the charging stroke is nearly completed. In this way the pressure in the cylinder is raised to 7 lb. per sq. in. The pressure in the reservoir was 16 lb. per sq. in., and dropped to the lower value at the end of the stroke. The reservoir still contains some air at a pressure slightly above 7 lb. per sq. in. and this air is used on the next exhausting stroke to act as the scavenging air. The engine is, in this manner, not only a supercompression engine but also a scavenging engine. Fig. 15 shows the design diagrammatically.

The Buckey Engine Co., Salem, Mass., built a twin-engine that used a scavenging pump in the rear of each power cylinder, in 1906. The manifolds in the engine were arranged in such a manner that each pump charged the other power cylinder.

In 1909, E. H. Micklewood, Plymouth, England, designed a two-cycle engine that scavenged as well as supercharged the cylinders. For this purpose the pistons and cylinders were of two sizes, the small one being the power piston, and the larger, the pump piston. The pump piston was double-acting, one side being used to furnish the charge while the other side compressed pure air for scavenging. Referring to the drawing at the extreme left of Fig. 16, *g* is the combustion-chamber of the power cylinder. As the piston is forced down by the power stroke, the upper part of the pump piston *h* is inducing a change, while the lower part compresses the air in the scavenging chamber *i*. As soon as the power piston uncovers the exhaust-ports, the intake-valve opens, the compressed air from *i* scavenging the cylinder. On the return stroke, the pure air in *g* and the mixture in *h* are compressed, until the pressure in *h* is higher than in *g* and the compressed charge is added to the charge in *g*.

F. Lamplough, an Englishman, designed a two-cycle engine in 1910 in which separate pump and power-cylinders acted on the same crankshaft. Each pair of power cylinders is connected to a single crank by an articulated connecting-rod. The pump passages are operated by a sleeve mechanism. Every other crank operates a pump cylinder, and is set at an angle of 180 deg. to the power-cylinder crank. The size and the location of inlet and exhaust-ports are the same. Due to the angularity of

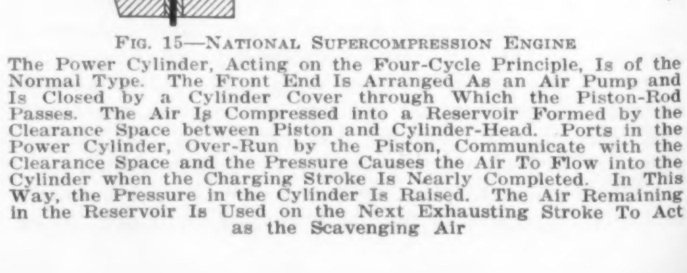

FIG. 15—NATIONAL SUPERCOMPRESSION ENGINE
The Power Cylinder, Acting on the Four-Cycle Principle, Is of the Normal Type. The Front End Is Arranged As an Air Pump and Is Closed by a Cylinder Cover through Which the Piston-Rod Passes. The Air Is Compressed into a Reservoir Formed by the Clearance Space between Piston and Cylinder-Head. Ports in the Power Cylinder, Over-Run by the Piston, Communicate with the Clearance Space and the Pressure Causes the Air To Flow into the Cylinder when the Charging Stroke Is Nearly Completed. In This Way, the Pressure in the Cylinder Is Raised. The Air Remaining in the Reservoir Is Used on the Next Exhausting Stroke To Act as the Scavenging Air

the connecting-rods, the exhaust and inlet-ports close and open at different times; the inlet-port remains open longer, thus permitting a larger charge to be forced into the cylinder by the pump. The two central drawings of Fig. 16 and that at the extreme right show the arrangement of the cylinder.

The same year, 1910, F. H. Smith, of Nottingham, England, designed a two-cycle engine using two pistons, one above the other; one piston was operated by a common crank-mechanism and the other by a specially designed cam. The shape of the cam is such that it permits changing the volume between the two pistons, thus compressing the charge between them. At a predetermined time, this compressed charge is pushed into the combustion-chamber. The drawing at the left of Fig. 17 shows the arrangement of this engine.

Sizaire Bros. and Marc Birkigt, both of France, also experimented in 1911 along the line of supercharger development, the former with a centrifugal compressor and the latter with two pumps placed in line with a four-cylinder engine.

The first American marine-type Diesel-engine was designed in 1913. It operated on the two-cycle principle and had a piston of two diameters, similar to that shown in the left half of Fig. 2. The piston having the larger diameter was used as a scavenging pump. A special scavenging valve controlled the time of injection of the scavenging air. No increase in power was sought by supercharging, except what was gained by the pressure of pure air in the cylinders after the expulsion of the exhaust residue.

In the same year, 1913, the Duplex Gasoline Motor Co., New York City, designed an engine having the compressor and the power cylinders arranged in pairs and acting on the same crankpin. The compressor cylinder takes in the air, compresses it and pushes it into the power cylinder at the top of the stroke. No combustion-chamber is necessary in this design. The arrangement of this engine is shown at the right of Fig. 17.

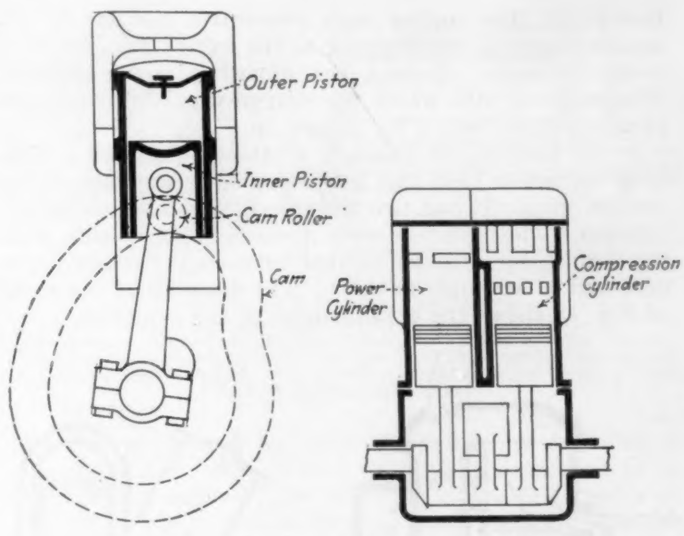

FIG. 17—THE SMITH AND THE DUPLEX ENGINES
The 1910 Design of the Smith Two-Cycle Engine Shown at the Left Used Two Pistons, One Above the Other; One Piston Was Operated by a Common Crank-Mechanism and the Other by a Specially Designed Cam. The Shape of the Cam Is Such That It Permits Changing the Volume between the Two Pistons, Thus Compressing the Charge. At a Predetermined Time, This Compressed Charge Is Pushed into the Combustion-Chamber. In the Duplex Engine Shown at the Right, the Compressor and the Power Cylinders Are Arranged in Pairs and Act on the Same Crankpin. The Compressor Cylinder Takes-In the Air, Compresses It and Pushes It into the Power Cylinder at the Top of the Stroke. No Combustion-Chamber Is Necessary in This Design

In 1914, the Record Engineering Co., of Eccles, England, designed a two-cycle engine that also uses a two-diameter piston for power and compressor cylinder, besides a piston valve to control the gas passages and a receiver to hold the mixture until ready for use. The operation of the engine can be seen easily from the diagrammatic sketch at the left of Fig. 18, in which j and k are the two pistons, l the piston valve governing the intake and m the receiver. In 1914, also, the De Launty gasoline engine was designed. The engine and pump

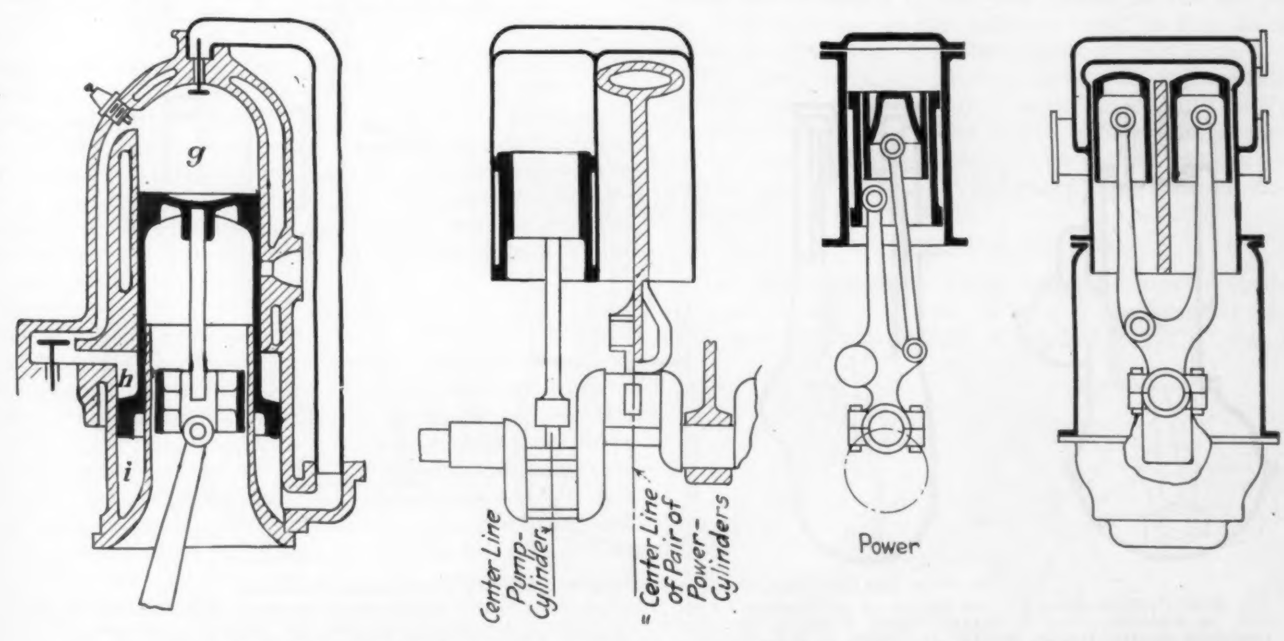

FIG. 16—TWO-CYCLE ENGINES OF MICKLEWOOD AND OF LAMPLOUGH IN 1909 AND 1910
Micklewood's Engine, Shown at the Extreme Left, Scavenged As Well As Supercharged the Cylinders. The Pistons and Cylinders Were of Two Sizes, the Smaller One Being the Power Piston and the Larger, the Pump Piston. The Pump Piston Was Double-Acting, One Side Being Used To Furnish the Charge While the Other Side Compressed Pure Air for Scavenging. The Two Central Drawings and That at the Extreme Right Illustrate Lamplough's Engine in Which Separate Pump and Power-Cylinders Act on the Same Crankshaft. Each Pair of Power-Cylinders Is Connected to a Single Crank by an Articulated Connecting-Rod. The Pump Passages Are Operated by a Sleeve Mechanism. Every Other Crank Operates a Pump-Cylinder and Is Set at an Angle of 180 Deg. to the Power-Cylinder Crank. The Size and the Location of the Inlet and of the Exhaust-Ports Are Similar

pistons in this engine were concentric, similar to the design shown in the drawing at the left of Fig. 2. Each pump, however, charged the opposing power-cylinder. The pressure with which the charge was forced into the power cylinder was 4 lb. per sq. in.

J. W. Lincoln, of London, England, designed a two-cycle engine in 1915 that had a double-acting compressor for charging. It had two power-cylinders and one pump-cylinder. The cylinders were arranged side-by-side, with the compressor cylinder located between the power cylinders and at an angle to them. The drawing at the right of Fig. 18 shows the arrangement of the cylinders.

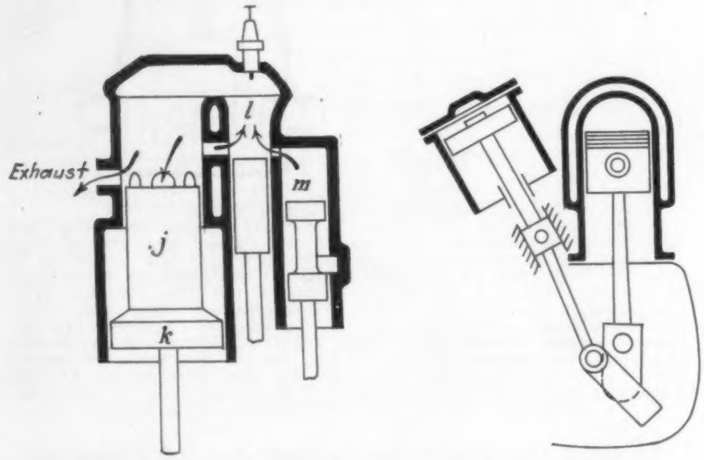

Fig. 18—The Record and the Lincoln Two-Cycle Engines
The Record Engine Shown at the Left Uses a Two-Diameter Piston for the Power and Compressor Cylinder, Besides a Piston Valve To Control the Gas Passages and a Receiver To Hold the Mixture until Ready for Use. The Lincoln Engine Shown at the Right Used a Double-Acting Compressor for Charging. It Had Two Power-Cylinders and One Pump-Cylinder. The Cylinders Were Arranged Side-By-Side, with the Compressor Cylinder Located between the Power Cylinders and at an Angle to Them

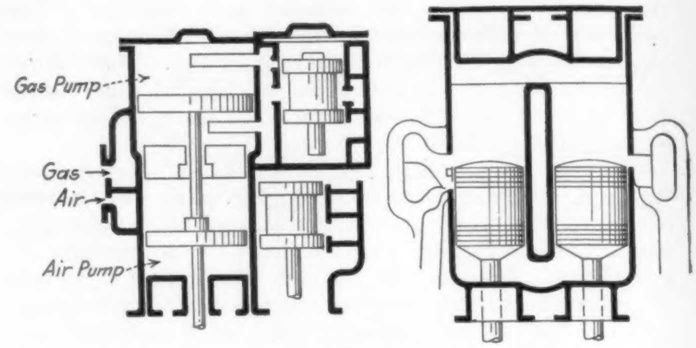

Fig. 19—Mather & Platt Engine of 1916
This Two-Cycle Double-Acting Vertical Gas-Engine Was Equipped with Special Air and Gas-Pumps Governed by Piston Valves. The Engine Was Composed of Two Units, Each of Which Had Its Own Pair of Power Cylinders Acting on the Same Crankpin, and Its Gas and Air-Pumps Having Separate Piston Valves. The Air-Pump Also Furnishes the Scavenging Air for the Cylinders, the Valve Mechanism Being Such That the Gas Is Not Mixed with Air Until It Arrives at the Entrance Ports of the Cylinders. For This Reason Special Air-Passages Are Provided for the Mixing Air, Apart from Those Used for the Scavenging Air

In 1916, Mather & Platt, of Manchester, England, built a two-cycle double-acting vertical gas-engine with special air and gas-pumps governed by piston valves. The engine was composed of two units, each of which has its own pair of power cylinders acting on the same crankpin, and its gas and air-pumps having separate piston valves. The air-pump also furnishes the scavenging air for the cylinders, the valve mechanism being such that the gas is not mixed with air until it arrives at the entrance ports of the cylinder. For this reason special air-passages are provided for the mixing air, apart from those used for the scavenging air. Fig. 19 shows the arrangement of the engine.

Ever since the invention of two-cycle engines, the compression in the crankcase has been used to furnish

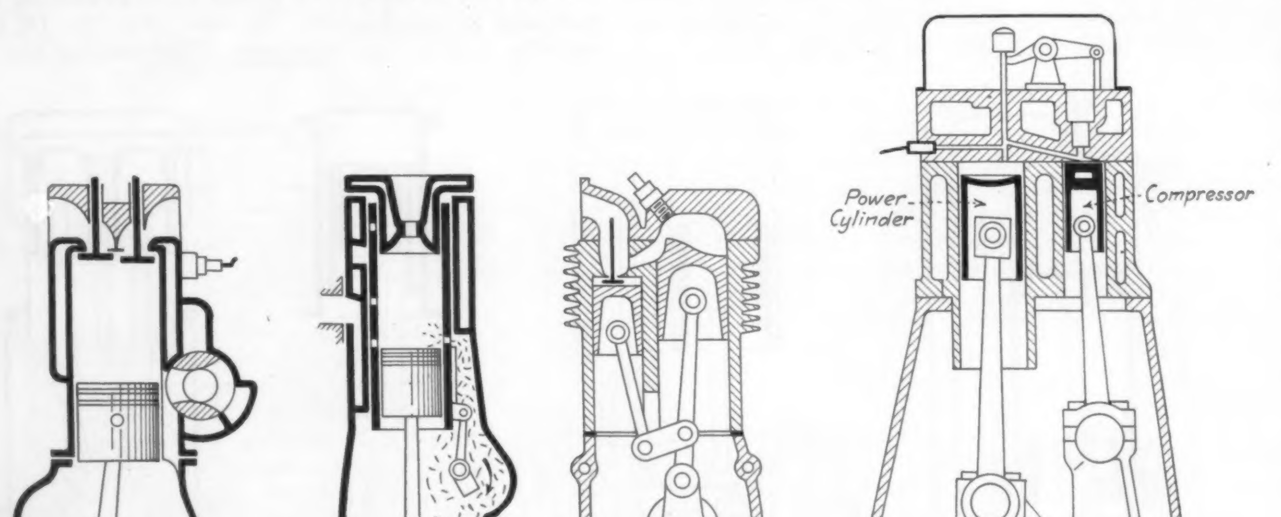

Fig. 20—The Kessler, the Wilson, the Grote, and the Hindlmeier Engines
The Four-Cycle Kessler-Engine Shown at the Extreme Left Was Equipped with the Customary Intake and Exhaust-Valves and, in Addition, with a Rotary Valve Forming the Connection between the Crankcase and the Cylinder. As the Piston Descends on the Intake Stroke, It Draws in the Ordinary Amount of Charge. At the Same Time, It Compresses the Air in the Crankcase. Just Before Reaching Bottom Dead-Center, the Rotary Valve Opens and, As the Piston Uncovers the Ports in the Valve, Air at a Higher Pressure Rushes-In, Filling the Bottom of the Displacement and Increasing the Pressure. The Total Charge Is Then Compressed and the Ordinary Four-Cycle Operation Is Then Completed. The Wilson Engine, Shown in the Left Central View, Uses the Same Principle as That of the Kessler Engine. Two Pistons and the Crankcase Compartment Form One Unit. The Two Pistons Work in Unison, Using a Common Crankpin. A Single Sleeve, Operated by a Connecting-Rod and Crank Governs the Gas Passages. The Grote Two-Cycle Engine Shown in the Right Central Drawing Uses a Separate Compressor for Supercharging and the Scavenging Is Done by the Crankcase Compression To Prevent Loss of Gas Due to Supercharging. The Small Diesel-Type Four-Cycle Hindlmeier-Engine Shown at the Extreme Right Was Designed for Automobile Use. Only a Portion of the Air Necessary for the Charge Is Compressed to a Pressure Sufficiently High To Assure Spontaneous Ignition

the air and fuel for scavenging and charging. The motorcycle industry especially has adopted this type of charging the cylinder. The first engine of this kind was built by Day, in 1891. A sketch illustrating the principle of its operation is shown in Fig. 1. This principle was made use of by Kessler in 1919 for supercharging his supercharged-engine. The engine operated on the ordinary four-stroke cycle. It was equipped with the customary intake and exhaust-valves and, in addition, with a rotary valve forming the connection between the crankcase and the cylinder. As the piston descends on the intake stroke, it draws in the ordinary quantity of

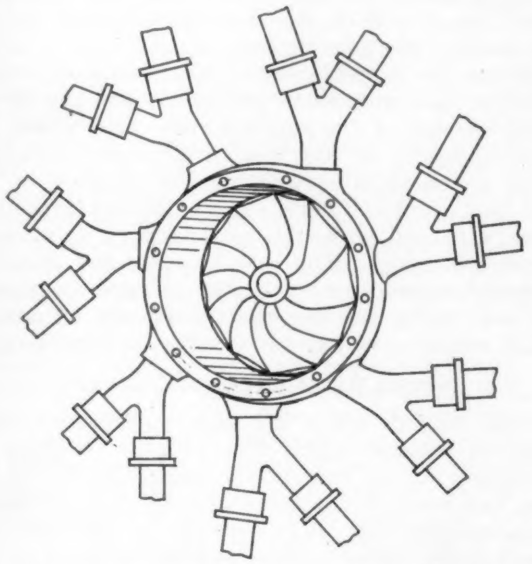

Fig. 21—Armstrong-Siddeley Jaguar Mixture-Distributor

In This 14-Cylinder Radial Aircraft Engine, the Rear Cover Comprises a Distributing Chamber for the Mixture. Within This Chamber, from Which Seven Branched Intake Pipes Radiate, Is a Blower or Centrifugal Fan Rotating at Crankshaft Speed. The Mixture Is Fed through the Center of the Rotating Unit, the Fuel and the Air Are Thoroughly Mixed and an Even Distribution to All Manifolds Is Claimed

charge. At the same time, it compresses the air in the crankcase. Just before reaching bottom dead-center, the rotary valve opens and, as the piston uncovers the ports to the valve, air at the higher pressure rushes in, filling the bottom of the displacement and increasing the pressure. The total charge is then compressed and the ordinary four-cycle operation is then completed. The drawing at the extreme left of Fig. 20 shows the arrangement of the engine.

The foregoing principle is followed by the supercharged-engine designed by F. M. Wilson in England in 1922. In this engine, two pistons and one crankcase-compartment form one unit. The two pistons work in unison, their cranks being set at an angle of 360 deg. to each other; that is, they utilize a common crankpin. A single sleeve operated by a connecting-rod and crank governs the gas passages. As the pistons are on their up-strokes, a double charge is drawn into the crankcase. As they descend, this charge is compressed. This completes the two-cycle operation of the crankcase charge. In the cylinder, however, a four-cycle operation takes place. While one piston is on the compression stroke, the other is on the exhaust stroke, this being obtained by the timing of the two sleeves. On the intake stroke of each piston, a charge is drawn into the cylinder in the ordinary manner, governed by the ports in the sleeves. Near the bottom of the stroke, the ports in the sleeve connecting the cylinder and the crankcase are opened

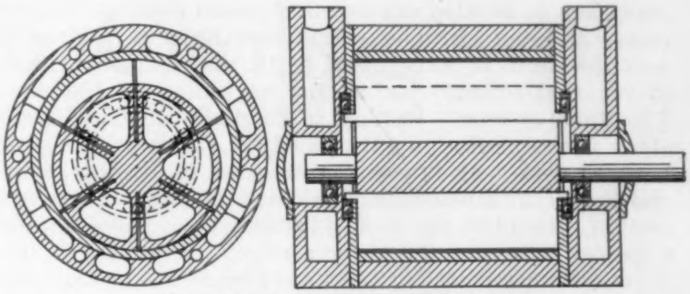

Fig. 22—The Malbay Compressor

To Avoid Friction-Losses and Rapid Wear, the Vanes in This Compressor, Instead of Sliding Over the Walls of the Outside Casing, Are Provided with Projections That Bear on an Eccentrically Located Ball-Bearing. The Small Amount of Play between Vane and Wall Prevents Wear

and the compressed air from the crankcase is added to the existing charge. The cycle is then completed as in the Kessler engine. The drawing at the left center of Fig. 20 shows a section through one cylinder. Another engine of this type is the one designed by Grote, in Germany, in 1922. This is a two-cycle engine using a separate compressor for supercharging, while the scavenging is done by the crankcase compression. This prevents loss of gas due to supercharging. A section through the engine is shown in the right central drawing in Fig. 20.

A small Diesel-type engine working on the four-cycle principle was designed for automobile use in 1922 by Joseph Hindlmeier, an Austrian. In this engine only a portion of the air necessary for a charge was compressed to a pressure sufficiently high to assure spontaneous ignition. The air is compressed in a single-cylinder air-pump or compressor driven by the engine crankshaft, the compressor being timed so as to deliver a charge of highly compressed air into the main cylinder at the moment the fuel is injected. The fuel is both atomized and ignited by the air charge. Fuel is supplied under pressure by a plunger-type fuel-pump. The compression pressure in the main cylinder is about 400 lb. per sq. in., while the pressure in the compressor is 700 lb. per sq. in. The drawing at the extreme right in Fig. 20 shows a sketch of a single-cylinder engine of this type.

The first idea of supercharging an automobile engine probably was conceived by Louis Renault in France in 1902, when he applied for a patent consisting of a centrifugal fan placed before the intake-manifold of an engine to increase the induction pressure of the gas charge.

Aircraft Engines

The examples given so far mostly comprise stationary and automobile engines. With the development of aviation and the continuation of the world war, it was found

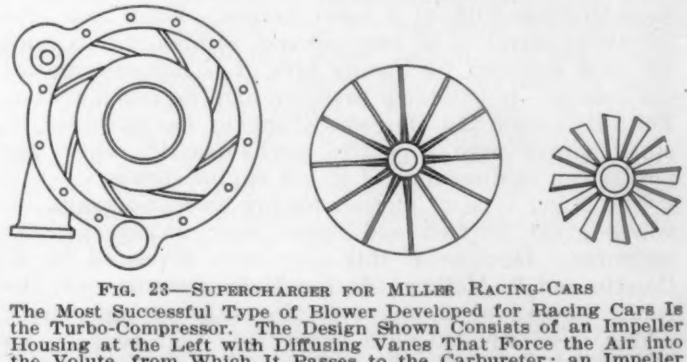

Fig. 23—Supercharger for Miller Racing-Cars

The Most Successful Type of Blower Developed for Racing Cars Is the Turbo-Compressor. The Design Shown Consists of an Impeller Housing at the Left with Diffusing Vanes That Force the Air into the Volute, from Which It Passes to the Carbureter; an Impeller with Radial Vanes Shown in the Central View; and the Entrance Buckets Which Are Shown at the Right and Are Placed Directly in the Center of the Housing Ahead of the Diffusing Vanes. The Buckets Make It Possible for the Air To Enter the Supercharger without Shock

necessary to develop engines that would generate higher power at great altitudes. Professor Rateau, in France, was the first to experiment with an exhaust-turbine-driven turbo-compressor at the beginning of the war. The Royal Aircraft Factory in England conducted tests along the same line in 1916 and 1917. This compressor, however, was gear driven. In America, E. H. Sherbondy and Dr. S. A. Moss were developing the Rateau patents in 1917. In 1919, the B. F. Sturtevant Co. had designed a gear-driven centrifugal-compressor. However, at the close of the war, none of them were ready for production. At the signing of the Armistice the following companies in Germany were ready for production with turbo-compressors: Schwade, Brown-Boveri & Co., Allgemeine Elektricitats Gesellschaft, and Siemens-Schuckert. The compressors developed were all gear-driven, and, according to the pressure required, were of the two, three and four-stage type. A sketch of the Schwade turbo-compressor is shown in the three views at the right of Fig. 5. In all airplane superchargers, fairly large quantities of air and gas were handled, while a pressure of 5 or 6 lb. per sq. in. was necessary to obtain best results.

While one of the requisites of the supercharger is to provide a charge under pressure to the cylinder, which can be achieved by all types of supercharger mentioned previously, the turbo-compressor has the additional advantage of mixing the fuel and air thoroughly and thereby providing a more even distribution. This last advantage was made use of by the Armstrong-Siddeley Co., in England, in 1917 to 1922, in the development of its 14-cylinder Jaguar radial engine. In this engine, the rear cover comprises a distributing chamber for the mixture. Within this chamber, from which seven branched intake-pipes radiate, is a blower or centrifugal fan, rotating at crankshaft speed. The mixture is fed through the center of the rotating unit, the fuel and air are thoroughly mixed and an even distribution to all manifolds is claimed. Further, at high speeds, a certain degree of forced induction is obtained. Fig. 21 is a sketch of the distributing chamber.

Supercharged Racing Engines

The first application of supercharging to racing engines was made in 1921 by the Mercedes Company. The compressor employed was the Roots blower, with two blades rotating at three times engine-speed. The increase in the speed of this car was 15 per cent above that without supercharging. This supercharger has been developed further by Sunbeam, Fiat and Alfa-Romeo engineers, in their 1925 cars having a displacement of 122 cu. in. The power developed this year by these small cars is claimed to be between 140 and 150 hp. or an increase of 35 or 40 per cent beyond that delivered by the same engines without a supercharger. While this type of blower seems to be very efficient at high speeds, such as those required for racing cars, it is not suitable for low speeds. It builds-up pressure only by accumulation. For this reason the Mercedes Company has provided its supercharger with a control mechanism by which the blower can be disconnected at low engine-speeds.

The Zoller type of blower, having eccentric vanes, involves great friction and rapid wear unless specially improved. Designs of this type were developed by R. Cozette and R. Malbay. In the Malbay compressor, the vanes, instead of sliding over the walls of the outside casing, are provided with projections that bear on an eccentrically located ball-bearing. The small amount of play between vane and wall prevents wear. Fig. 22 shows a sketch of this compressor.

At present, the most successful type of blower developed for racing cars is the turbo-compressor used by Dusenberg and Miller, being a modification of the airplane compressors by Professor Rateau, Dr. Moss and Schwade. The first compressor of this type for racing cars was designed for Duesenberg. The design used by Miller in his racing cars is shown in Fig. 23. It consists of (*a*) an impeller housing with diffusing vanes that force the air into the volute, from whence it passes to the carbureter; (*b*) an impeller with radial vanes; and (*c*) the entrance buckets, placed directly in the center of the housing ahead of the diffusing vanes. These buckets make it possible for the air to enter the supercharger without shock. Both the Duesenberg and the Miller superchargers are gear-driven.

Whether the figures relative to the power output of the racing cars mentioned previously are the direct results of the use of the supercharger, or whether a general development of the design of their engines constitutes a considerable part of the increase in power cannot be determined here, since extensive tests on these engines with and without superchargers, if made, have not been published. The best proof of the efficiency of the supercharger in promoting an increase in power and speed is given by the fact that practically all companies building racing cars have adopted it as standard.

Supercharged Diesel-Engines

Another field in which the supercharger has obtained commercial success is the Diesel-engine industry. The supercharger, in the case of its application to the Diesel engine, has been of the same general type as described in the preceding text. It is, however, of somewhat larger size and lower speed. The notable increase in power and speed in the supercharged Diesel-engine now bids fair to supersede all other types of drive for ship propulsion.

A few figures regarding the power output of one of the latest Diesel engines for marine use will illustrate this best. The Allgemeine Elektricitats Gesellschaft turbine factory in Berlin has completed the Diesel installations for two 20,000-ton steamers designed for a speed of 12 knots and developing 6400 hp. By the use of an electrically driven turbo-compressor for supercharging, the speed can be increased to 13 knots and the power output to 7800 hp., a 22-per cent increase in power.

Supercharger Development for Passenger Cars

The history of the supercharger to date is now complete; but the question then arises regarding how much it will influence the development of the supercharger for passenger cars. The requirements for this type of car vary greatly from those of the airplane engine, Diesel engine or racing car. Mere increase of intake-manifold pressure without other changes will result merely in increase of power at maximum speed. Is it not possible to design a supercharger that would result in a greater torque at low speed? If this is possible, the supercharger not only would provide greater power from the same displacement of the engine but also greater flexibility, the lack of which in the present engine is the limiting factor of the utility of the internal-combustion engine. If this can be achieved, it would mean the modification of the transmission, which is the most undesirable part of the automobile. The size of the engine could be reduced to that required for normal working-conditions on level roads, with the supercharger taking care of the necessary reserve power for hill climbing and acceleration.

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Evaporative Cooling

By HERBERT C. HARRISON[1]

DETROIT SECTION PAPER *Illustrated with* CHARTS AND DRAWINGS

ABSTRACT

FIRST taking exception to the term "steam cooling" because of its association with steam heating, and suggesting "evaporative cooling" as more appropriate, the author describes the results of 7 years' experimentation with various modifications of an original system and declares that the latter has proved itself to be the most satisfactory.

The problem is stated to be merely that of cooling an internal-combustion engine with boiling water, using the water as a carrier of the steam produced to transfer the very considerable quantity of heat contained in the steam to a system suitable for condensing the steam and wasting its latent heat by condensation.

After detailing the many shortcomings of the conventional water-cooled system, which include the liability of the system to become stagnant because of the formation of steam-pockets and the consequent inoperativeness of the pump; the excessive size of the radiator required to meet the maximum demand while running with wide-open throttle, at maximum possible speed, in a hot climate, or at a great altitude; the unsuitability of such a radiator for normal operation during the greater part of the year; and the problem of crankcase-oil dilution due to overcooling, the advantages of evaporative cooling are outlined.

Although the problem of allowing water to boil in the cylinder jackets, the steam formed to be condensed and the condensate to be returned does not seem difficult, many practical considerations must be taken into account.

Experiments with numerous variations of the original system are described, such as operating at a variable or a fixed pressure; at subatmospheric, atmospheric or superatmospheric pressure; with the steam circulating downward as in ordinary radiator practice, from side to side or introduced at the bottom and allowed to flow upward; or with dry steam, wet steam or steam and water.

Of these variations the most satisfactory combination is said to be that in which wet steam containing water is introduced into one side of the radiator-core, the water being allowed to traverse the lower tubes and the steam the upper tubes of the radiator. The steam in crossing the radiator is condensed and trickles down to the water and both are returned by one pump to the cylinder-block.

The general principles said to apply to successful operation include:

(1) Rapid circulation of water through the jackets into the cooling-system

(2) Maximum temperature-difference between the air and the core

(3) A centrifugal pump operating with slightly cooled water, a gear-pump being undesirable

(4) Prevention of an air-lock in the condenser, and the venting of the cold side of the condenser to the atmosphere

(5) Provision for the care of residual heat in the cylinder-block to minimize the loss of steam after hard driving and sudden stopping

(6) No loss of water or alcohol under any circumstances

(7) No retardation of rate of circulation of steam

(8) Air-flow and rise of temperature of the air dependent on the volume of air passed and the turbulence within the radiator

(9) Interchangeability of the condenser with a standard radiator

(10) Capacity, when fully filled with water, of operating as a superior water-cooled system

IN discussing the subject of "steam cooling," I shall give an account of the work that we have been doing in the last 7 years and the conclusions that we have reached. At the same time, I should like to take exception to the term "steam cooling." We all are acquainted with steam heating; and I believe that at least some of the resistance encountered by this new evaporative cooling-system has been due to the unfortunate designation of it by this term.

No basis in fact or function exists for this misnomer. It is true that, in the cylinder-jackets, water is caused to boil and steam to be formed; but the steam so formed is a very small part, by weight, of the cooling fluid and, having a low specific-heat, has practically nothing to do with the cooling of the cylinder-block. If, again, we look at the other half of the system, the radiator or condenser in which the steam is condensed, we find that it is an ordinary air-cooled condenser, in which the steam is condensed and the resulting water is cooled.

The cooling, of course, is produced by the evaporation of water into steam in the engine jacket, and by the conveying of the steam to an air-cooled condenser where its latent heat is given up. This may seem a small point; but engineers have associated the formation of steam in the jackets of a combustion-engine with poor engine performance for so long a time that I should like to have a new name adopted to describe this system, which promises relief from many troubles essentially incident to a standard water-cooled combustion-engine.

I realize that in the last 2 years much interest has attached to this subject; many papers have been read before the Society, and many interesting articles have appeared in technical papers. For this reason, I shall endeavor, not to go over old ground more than is necessary, but to give a comprehensive view of the development of this style of cooling-system, insofar as it can be applied to an automobile, from the time that interest began to be attracted to it.

SHORTCOMINGS OF WATER-COOLING

The shortcomings of the water-cooled system are well known to us all; but in spite of them it has held the field for the last 25 years as the most practical method of cooling automobiles. Water was used in the cooling-system originally because it was the liquid most easily

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obtainable for general use, acting as an intermediate agent to receive the heat from the cylinder-block and, in turn, giving it off to an air-cooled radiator of special design that was placed in the circuit, through which the water was caused to flow.

Water boils at 212 deg. fahr. and, for this reason, such a system had a definite temperature above which the water leaving the jacket could not be allowed to rise; because, if the water was caused to boil violently, a great danger existed of steam-pockets occurring in the head; and the pumps used to circulate the liquid were liable to fail, because they were unsuited to circulate water at a temperature near its boiling-point. Under such conditions such a system would become stagnant, due to the formation of steam and the inoperativeness of the pump and, through its inability to absorb the heat from the block would quickly develop pressure and continue to allow the temperature of the block and of the exhaust-valves to rise to a degree not consistently allowable with the good operation of the engine itself.

We were confronted, therefore, with the necessity for making all water-cooled radiators large enough to take care of the most severe demands ever to be required: that is, of cooling the engine continuously while running with wide-open throttle, at the maximum possible speed, in a hot climate or at a great altitude. Obviously, a radiator capable of performing satisfactorily such duty must have many times the cooling-capacity required by the same car in cold weather, when operated at part throttle; in other words, a radiator chosen for safety in high-duty performance is unsuitable for normal operation during the greater part of the year. Furthermore, since the quality of gasoline has continually been getting poorer, the secondary ill-effects of overcooling have become more apparent; and today there is probably no engineer who has not to some extent considered the problem of crankcase-oil dilution due to overcooling. To mitigate this, shutters, or devices equivalent to shutters, are being adopted by many of the best automobiles; these shutters control and limit the airflow, either thermostatically or otherwise, so as to reduce the cooling-capacity of the radiator-core.

We see, therefore, that a standard water-cooled system, however designed, cannot be made suitable for widely varying conditions of climate and of driving. Danger from overheating, danger from overcooling, apart from freezing, and a certainty that under all conditions heat will be taken from the system and thrown away in a quantity that bears little relation to the necessity for the rejection of heat, are all present. That all the heat which can be conserved without interfering with the operation of the engine will tend toward economy of fuel is obvious.

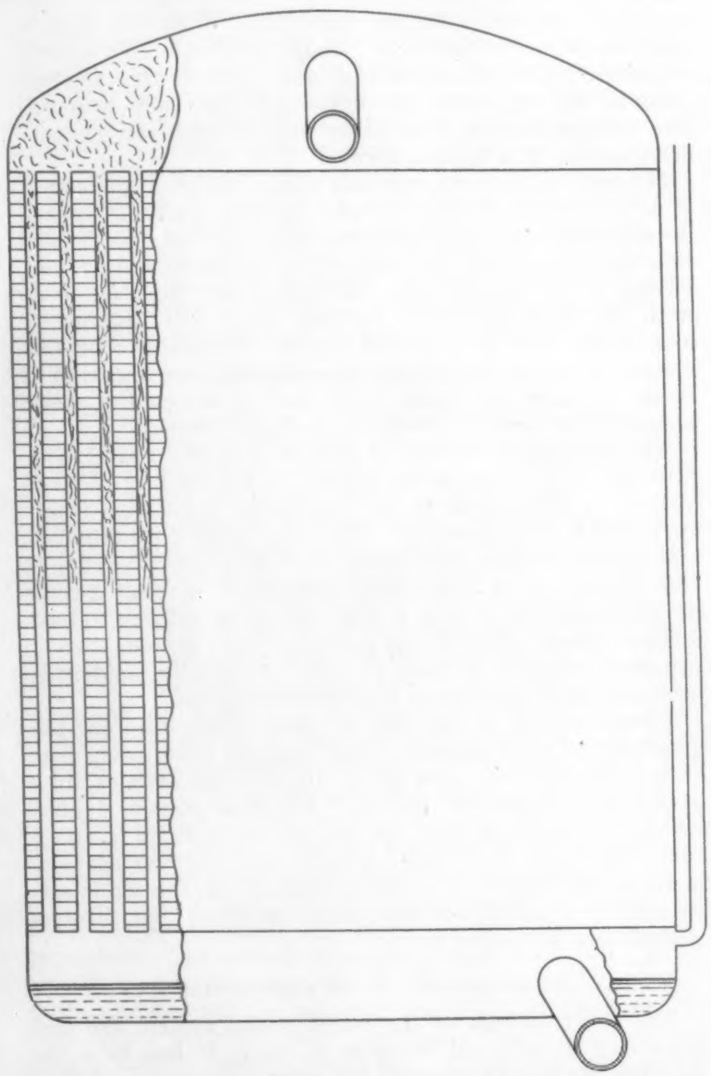

FIG. 1—FIRST METHOD OF VARYING THE CIRCULATION
The Steam Circulates Downward as in Ordinary Radiator Practice and Is Condensed and Withdrawn from the Bottom Tank

PRINCIPLES OF EVAPORATIVE COOLING

The general proposition of evaporative cooling is not new. For many years hopper-cooled engines have been in operation, in which, with a very open head, water is allowed to boil away to the atmosphere, the excess heat in the engine being used to convert the water into steam at atmospheric pressure. The theory is perfectly sound, since a constant-temperature engine is obtained in this way. A rapid internal circulation in the jackets and the hopper head was obtained by the high turbulence produced by the boiling, and no excessive temperatures of the metal in any part of such a system need be expected, even under heavy loads, provided that sufficient water is kept in the system, and the engine is of reasonable design and will allow the free escape of the steam generated.

To consider cooling automobile engines in such a way that the water in the jackets will be allowed to boil away freely and be lost is impracticable. We must condense the steam that is formed, therefore, and return it to the system; and this means a closed or semi-closed system, which will include a condenser in circuit with the steam that will condense the steam and allow the water so formed to be returned without loss.

The problem originally was to suit all practical conditions, so that an automobile engine could be cooled by allowing the water to boil in the cylinder-jackets, the steam formed to be condensed, and the condensate returned. This at first does not sound like a very difficult problem; but a great many practical considerations must be taken into account, and a great many different ways and combinations of ways in which systems that will operate more or less practically can be made. For instance, such a system can be operated at a variable or at a fixed pressure; if subatmospheric, the water will boil at a temperature below 212 deg. fahr.; if atmospheric, the cold side being vented to the atmosphere, the water will boil at approximately 212 deg. fahr.; if superatmospheric, as a partly closed system, in which pressure, variable or controlled, will develop, the water will boil at a temperature above 212 deg. fahr.

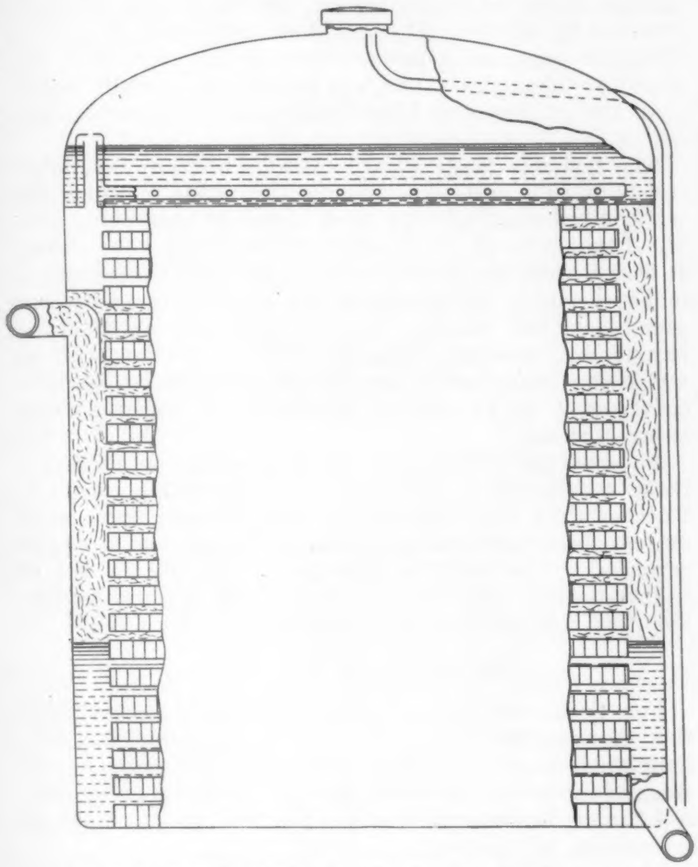

FIG. 2—SECOND METHOD OF VARYING THE CIRCULATION
The Steam Circulates from Side to Side of the Radiator, Entering One Side, the Resulting Water Being Withdrawn and Returned from the Opposite Side

VARIATIONS OF ORIGINAL SYSTEM

As a second set of variations, a radiator could be provided in which the steam will circulate downward as in ordinary radiator practice, will be condensed and will be withdrawn from the bottom tank (Fig. 1); or the steam can be made to circulate from side to side of the radiator, entering at one side and the resulting water being withdrawn and returned from the opposite side (Fig. 2); or steam can be introduced at the bottom of the radiator and allowed to flow upward, the condensed water falling down the same passages and being returned to the cylinder-block (Fig. 3).

It is also possible to provide a cylinder-block head that will form a steam-dome, so that only dry steam can be passed to the radiator condenser; or, if a standard head is used, wet steam or steam and water can be passed through it into any of these types of condenser. In either case, to form separate circuits to circulate the boiling water and to condense the steam, which may be returned to the cylinder-block separately or together, is possible.

A review of the history of our work for 7 years, during which we have carefully investigated every one of these variations, will enable definite conclusions to be drawn as to which of these combinations will offer the maximum advantage; for eventually, when these systems become common practice, only the most deserving will survive.

CONDITIONS PRODUCING MAXIMUM ADVANTAGE

I will enumerate a few of the more important points, which are

(1) A constant-temperature fluid is provided as the cooling agent surrounding the cylinder-block, irrespective of climatic conditions or of the power developed; and this constant temperature is obtained without the use of thermostats, since the water is the thermostat of the system, the temperature being controlled only by the pressure, which, in turn, definitely fixes the boiling-point of the cooling liquid

(2) The temperature of the cooling liquid being substantially 212 deg. fahr., crankcase-oil dilution is practically eliminated

(3) Volatile anti-freeze mixtures can be added without loss, if the system is properly arranged

(4) The condensing radiator, even if frozen, provided that no anti-freeze mixture is present, will be self-thawing in operation

(5) Great economy can be expected in operation under part throttle during cold weather

(6) Economy in oil, due to more constant conditions of lubrication can be expected under any conditions

(7) As cold-weather driving can be ignored the carbureter can be set for a hot engine

A condensing system has brains. It will not eliminate heat unless heat should be rejected from the system, but will adjust its size automatically to the needs of heat rejection. In other words, to sum up all these points: The best kind of summer driving is provided in summer

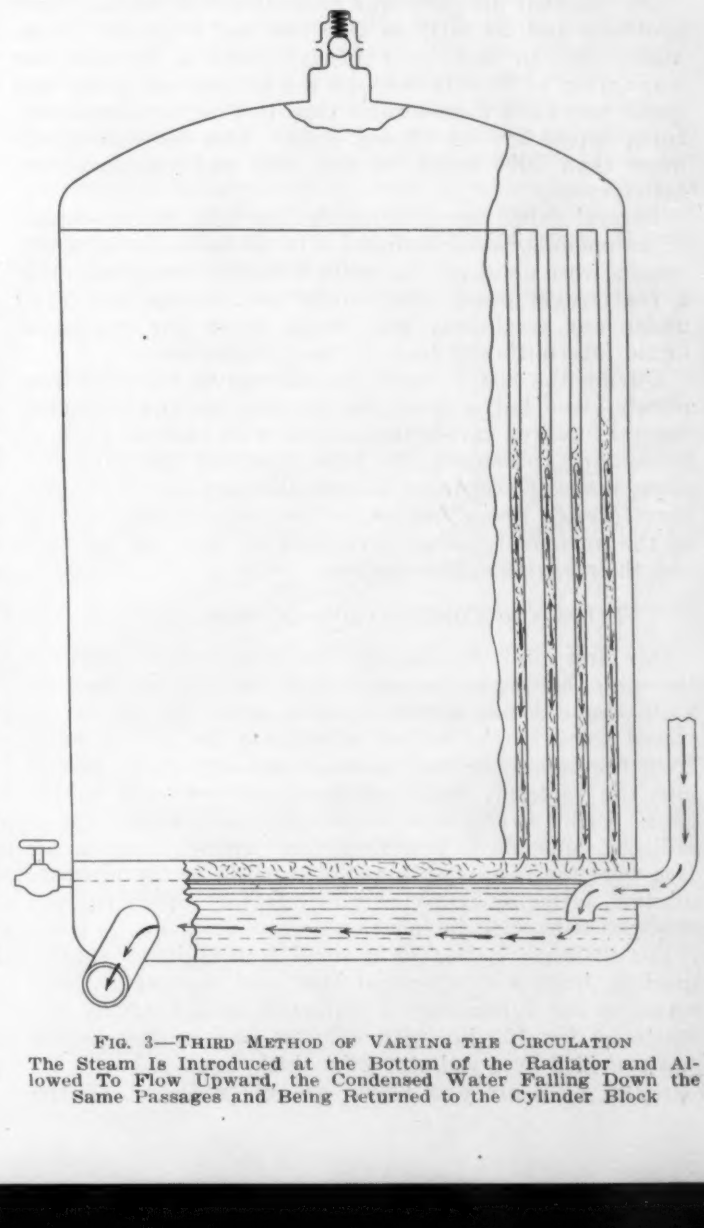

FIG. 3—THIRD METHOD OF VARYING THE CIRCULATION
The Steam Is Introduced at the Bottom of the Radiator and Allowed To Flow Upward, the Condensed Water Falling Down the Same Passages and Being Returned to the Cylinder Block

or winter, in Alaska or Florida, with one standard cooling-system.

History

The possibility of using this system was brought to my notice in 1918 by Wellington W. Muir, who had already obtained patents on a cooling-system. The general idea was not entirely new, but the particular solution that we first investigated was new. This was a variation in which a separate circuit was provided for the circulation of the boiling water, preferably by a pump, a subsidiary circuit for the circulation of the steam through the radiator-condenser and the return of the condensate to the cylinder-block. Nothing was wrong with the operation of this system when properly installed but, in endeavoring to introduce it to the trade, considerable opposition was encountered because two pumps appeared to be necessary, or at least highly desirable, to operate the circuits satisfactorily. We continued to experiment with variations, with a view to eliminating the pumps or to combining the two into one.

Here it was obvious that satisfactory operation could be obtained, provided, first, that the main pump through which the hot water was circulated would operate when pumping boiling water and, secondly, that the secondary pump for returning the condensate would lift the condensed water back to the cylinder-block under all conditions.

No inherent difficulty was encountered in solving these problems and, as early as 1919, we had a number of installations; in fact, in February, 1919, a Packard car was driven to Florida through the ice and snow, and was under test for a considerable time in Florida in temperatures approximating 92 deg. fahr. This car was driven more than 2000 miles on this trip and operated very satisfactorily.

Several other cars, including the best known makes of automobile, were equipped. In all cases, satisfactory results were obtained, the main difficulty being to supply a centrifugal pump that would not become air-locked under any conditions and would throw the condensed liquid intermittently back to the cylinder-block.

During the last 7 years, in addition to building completely about half a dozen special cars, we have equipped several hundred cars satisfactorily with various kinds of condensing radiators. We have operated test cars over more than 500,000 miles during this period. It is fair, therefore, to generalize as to the possibilities involved in the various types of arrangement that can be used and their various combinations.

Types and Combinations of Arrangement

Our first effort to simplify the system was to cut-out the main boiling-water circulation, relying on specially built steam-domes either integral with the engine or placed above it that served to separate the boiling water from the steam, so that more or less dry steam passed into the radiator, was condensed and returned to the block. Such systems were investigated with every type of radiator, downflow, crossflow and upflow, but in no case were the results obtained believed to be the ultimate solution, although thoroughly satisfactory operation was obtained with such installations.

For instance, a test of a small four-cylinder engine, specially built with a special head and running at 2000 r.p.m. on the dynamometer with wide-open throttle, was continued for 100 hr. with only its own cooling, which was provided by a radiator 2 in. thick, equipped with its own fan. No air was blown on this radiator, all the cooling being accomplished by the air drawn through the core by the fan. It is interesting to know that after this test was over a power-curve of this particular engine was taken again, and was found to be slightly better than the power-curve taken immediately before the test began.

The test was made with double circulation; but, after concluding the test, experiments were made in which the water circulation was not used, a special head being provided that allowed ample space for separating the steam. It was possible to operate such a combination with only a make-up pump, for returning the condensate to the engine-block; but this was largely due to the fact that the engine was specially designed, with a special head in which the water spaces around the block were specially constructed to prevent a possibility of steam-pockets being formed.

It would be difficult, if not impossible, to duplicate these results with most standard automobile engines. Further than this, any system that depends upon more or less dry steam being condensed in the radiator and returned to the block practically necessitates the use of a gear-pump. The use of a gear-pump is so objectionable that it is hardly worth considering.

Circulation of Wet Steam

For these reasons, we early came to the conclusion that it was preferable, if the use of one pump was contemplated, to circulate wet steam together with a considerable quantity of water, and to cause the separation to be made in some part other than the cylinder-head of the engine.

I have now come to the point where the desirable lines of research contemplate the circulation of wet steam combined with water by one pump; and we investigated carefully the relative merits of subatmospheric, atmospheric and superatmospheric pressures. Subatmospheric operation introduced complications without any apparent advantage whatever, because a temperature of 212 deg. fahr. of the jacket-water was not too hot for good operation, and the troubles introduced by artificially lowering the pressure in the radiator brought no corresponding advantage.

Similarly, operation at superatmospheric pressure brought no advantage but, in fact, a very distinct disadvantage. Although it is true that 212 deg. fahr., and probably some slightly higher temperature, is not too hot, yet 212 deg. fahr. is a very convenient temperature to use for jacket-water. Superatmospheric pressure, if allowable, would be very difficult to control, and temperatures much above 212 deg. fahr. might be distinctly harmful to the operation of the engine. For these reasons, for the sake of simplicity and good operation, superatmospheric systems were abandoned.

Atmospheric pressure is the remaining choice. It affords the simplest, easiest and, luckily, the most suitable temperature for the jacket-water. In any such system, whether the condenser is arranged for down flow, cross flow, or up flow, the cold side of the condenser is freely vented to the atmosphere.

If downflow, or standard, radiator-practice is followed and steam and water are introduced at the top of the radiator, the radiator will operate perfectly, unless the overflow vent, which is now located in the bottom tank, becomes immersed in the condensate in the bottom tank, or the water in the bottom tank rises to the core level. In either case, pressure will be formed in the radiator, and water will be expelled from the system. To avoid these occurrences is not impossible; but anything that

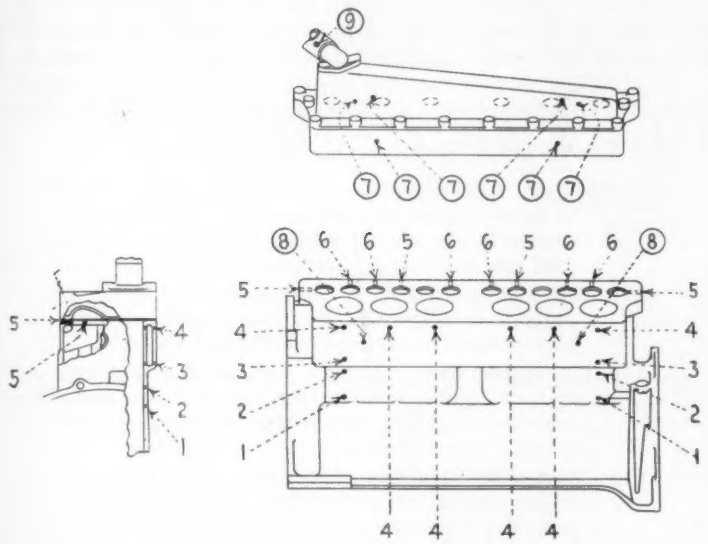

FIG. 4—CYLINDER-BLOCK METAL TEMPERATURES OF CONSTANT-TEMPERATURE ENGINE

The Engine Has Six 2¾ x 4¾-In. Cylinders. The Compression-Pressure at 1000 R.P.M. Is 87 Lb., Gage. The Figures in Circles Represent Points at Which Temperatures Were Taken with Thermometers. Thermocouples Were Used at All Other Points

fails or causes the water to rise in the bottom tank will cause a loss of water to the system.

On the other hand, with an upflow radiator, the steam obviously will not rise in the radiator-core unless some pressure is formed to force it up. Unless pressure causes the steam to displace the air, no cooling will take place. Furthermore, if a pressure vent is provided so that the steam is forced up into the radiator-core, it will work satisfactorily if the radiator passages are large, the power is small and the water formed in the core can trickle down the same tube that the steam is trying to ascend; but in every case such systems will fail when heavily taxed, because the water will not readily fall down the same tube to the high-pressure side from which the steam is trying to rise. The water will be pushed into the top tank and finally out of the overflow. This is inherent in all such systems and can be demonstrated by operation on any hard hill, for example, where a steady pull of about 2 miles will allow the radiator temperature to settle under full load.

Analogy to Traffic Conditions

An analogy taken from traffic conditions will clearly illustrate the predicament in which the water will find itself in an upflow radiator-condenser: The water is like a single car in a one-way street going against the traffic and trying to make good time.

Another variation consists of the introduction of wet steam containing water into one side of the radiator-core, allowing the water to traverse the lower tubes and the steam the upper tubes of the radiator. The steam will be condensed in crossing the radiator and will trickle down to the water that collects at the bottom; and both can be returned by one pump to the cylinder-block. In other words, it is an ideal exemplification of our original effort, namely, two independent circulations of water and steam, the only difference being that all the circuits are contained within the radiator and not in pipes exterior to it. As a matter of fact, this arrangement according to our experience is the last word in the logical solution, being an exact return to the first successful layout in 1918. The water circulation is independent of the steam circulation and, by an ingenious arrangement of the radiator, the principal trouble attending all installations, namely, air-locking of the pump, is avoided, since a free-air vent is provided on the solid side of the radiator. It is worthy of note that after some 6 years' work, we had to return to the original solution to obtain results that have overcome every criticism directed at these systems to date.

Use of Centrifugal Pump

One interesting variation remains that we were forced to adopt in certain cases for the sake of expediency. The system will not operate with an ordinary centrifugal-pump, unless the level of the pump is such that the pump will be self-priming with water, and can free itself automatically from air by venting back to the cold side; but in some cases the pump is located in front of the cylinder-block, about half-way up the radiator. In such a case we can adopt a variation of this system, which is similar to the original, namely: By allowing the water level to rise to a point at which the pump is self-priming, the water will circulate through approximately one-half, or a little more, of the tubes of the radiator, only one-half of the core being utilized as a condenser. Such an arrangement will run too cool under part throttle, and will not have a truly constant temperature unless means are taken to check the flow of water through the jackets. This can be done, however, by putting a baffle-plate in the pump-suction line, which normally allows a small quantity of water to pass to the pump. When boiling occurs in the cylinder-jacket, the distension of the liquid causes the water to overflow the baffle-plate, augmenting the quantity of water available for the pump supply, immediately increasing the circulation, and reducing the temperature of the liquid, and consequently its level, to that at which this additional circulation is caused to stop. This is a very interesting development of the system and is applicable to cases in which the pump is located at an artificially high level. It has proved satisfactory and is capable of being installed on practically any water-cooled automobile.

In much of the previous discussion before the Society,

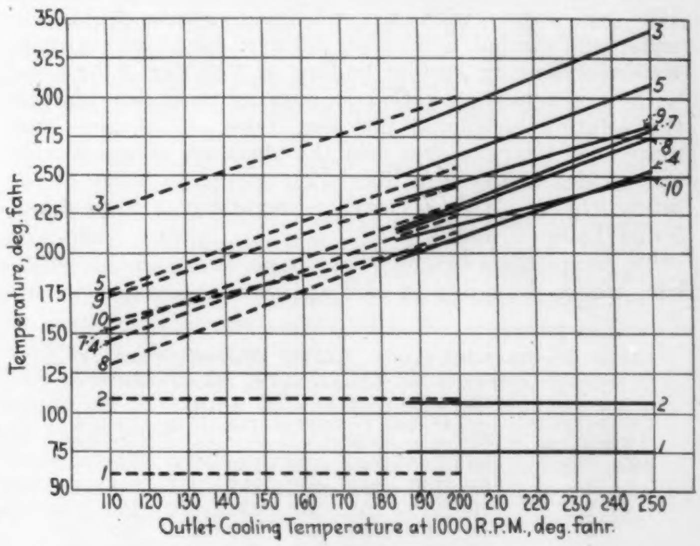

FIG. 5—COMPARATIVE CYLINDER-BLOCK TEMPERATURES ON WATER-COOLED AND STEAM-COOLED RUNS

The Dashed Lines Indicate the Water-Cooled, the Full Lines the Steam-Cooled Runs. The Engine Had Six 2¾ x 4¾-In. Cylinders. The Compression-Pressure at 1000 R.P.M. with the Engine Cold Was 87 Lb., Gage. In the Water-Cooled Runs, Arctic Oil Was Used at 133 to 142 Deg. Fahr.; Room Temperature, 82 to 84 Deg. Fahr.; Barometric Pressure, 29.25 In. of Mercury. In the Steam-Cooled Runs, G.M.A.-30 Oil Was Used at 140 to 168 Deg. Fahr.; Room Temperature, 83 Deg. Fahr.; Barometric Pressure, 29.50 In. of Mercury

TABLE 1—CYLINDER-BLOCK METAL TEMPERATURES OF A CONSTANT-TEMPERATURE 2¾ X 4¾-IN. SIX-CYLINDER ENGINE OPERATING AT 400 R.P.M.

Temperature Location	Outlet Temperatures, Deg. Fahr.							
	Water						Steam	
(See Fig. 4)	110	130	140	170	190	200	183	212
1	145	155	164	186	210	215	202	215
2	150	166	180	206	230	240	223	238
3	130	149	161	191	218	226	209	225
4	145	161	172	201	226	237	217	232
5	164	182	191	216	245	252	228	238
6	136	155	163	186	216	225	211	229
7	110	129	140	170	189	199	182	208
8	107	126	137	167	187	197	181	207
9	110	130	140	170	190	200	182	208

a very pertinent factor has been overlooked. Two problems are concerned in evaporative cooling: one, to get the superfluous heat from the cylinder-block into the boiling water, vaporizing a portion of it; the other, to convey the steam and water to a conveniently situated heat-waster, which will condense the steam and from which both the condensed steam and the water can be returned to the system.

Value of Turbulence in Abstracting Heat

The first point has been fairly well covered in previous discussions; and it has been pointed out that, owing to the turbulence of the boiling water and in spite of the fact that steam itself is a heat insulator and water a poor conductor, violently boiling jacket-water is a good medium for abstracting heat from the cylinder-block, provided that the steam can be removed as soon as it has been formed. This indicates a high rate of water circulation, so that the water itself, carrying little heat, will convey the steam, the heat-container, to the condenser.

That, with boiling water in the jacket, we may expect lower temperatures of the metal at the exhaust-valves or other parts of the block than we would with water at 170 deg. fahr., is not true, although this has been suggested. The fact is that the temperatures of the metal vary closely with the temperatures of the cooling fluid. We have made actual measurements of these temperatures with a standard water-system containing water at 170 deg. fahr., with a condensing-system containing water and alcohol, boiling at 185 deg. fahr., with a plain water-condensing system boiling at 212 deg. fahr., and with a condensing-system containing calcium chloride, the solution boiling at 260 deg. fahr. It is true that more even temperatures over the block are obtained with any condensing-system than with any plain water-circulating system. This is clearly brought out in Figs. 4 and 5 and Tables 1 and 2.

To recapitulate briefly, there is no magic in this problem, which is merely to cool an internal-combustion engine with boiling water, using the water as a carrier of the steam produced to transfer the very considerable quantity of heat contained in the steam to a system suitable for condensing the steam and wasting its latent heat by condensation. Certain general principles apply:

TABLE 2—CYLINDER-BLOCK METAL TEMPERATURES OF A CONSTANT-TEMPERATURE 2¾ X 4¾-IN. SIX-CYLINDER ENGINE OPERATING AT 1000 R.P.M.

Temperature Location	Outlet Temperatures, Deg. Fahr.							
	Water						Steam	
(See Fig. 4)	110	130	140	170	190	200	183	212
1	165	175	185	202	212	221	215	233
2	170	190	201	222	231	242	233	255
3	138	158	166	196	212	224	213	237
4	155	178	189	215	226	238	222	241
5	215	230	240	249	252	257	237	255
6	160	175	188	212	222	234	225	244
7	108	131	138	169	188	199	185	212
8	104	126	135	165	185	196	179	203
9	109	131	140	170	189	201	185	212

General Principles of Operation

(1) Water, being a non-conductor and serving mainly to carry the steam, which is the heat-container, should be circulated rapidly through the jackets and into the cooling-system

(2) The cooling-system, or condenser, should be arranged to allow the maximum mean temperature-difference between the air and the core

(3) The water itself need not be cooled, but a centrifugal pump will operate better if the water is cooled slightly; and, from experience, a gear-pump is undesirable

(4) The system should be arranged so that there will be no chance of an air-lock in the condenser; and the cold side of the condenser should be vented to the atmosphere

(5) Provision should be made to take care of the residual heat in the cylinder-block, to avoid or minimize the loss of steam or water after hard driving and sudden stopping

(6) The system under no circumstances should be capable of loss of water or alcohol, under the hardest continuous driving for indefinite periods

(7) The efficiency of the condenser will depend largely on the rate of circulation of the steam through it, and nothing should be allowed to retard this circulation

(8) The air-flow and rise of temperature of the air are interdependent, depending on the volume of air passed and the turbulence within the radiator; but we also must take into consideration the total resistance to air-flow of the system, including the hood

(9) The system should be capable of being installed in a standard car without altering anything whatever, merely replacing the standard radiator with a condensing one

(10) If fully filled with water, the system should be capable of being run as a superior water-cooled system, until the prejudice due to the name "steam-cooling" has been overcome. When fully filled with water, as a cross-flow water radiator, the system is distinctly superior to present-day water-cooling practice. The pressure exerted by the pump serves to boost the circulation through the core, since the cold side is vented, and not the hot side, as is the usual practice. This tends to retain the alcohol, and is very important at great altitudes, since the temperature of the boiling fluid is actually lower than at sea-level, and no heating troubles need be expected. Mechanical losses and vacuum on pump suction are avoided through the overflow. The system will stand greater overload than standard systems and, if loss of water should occur, will become an evaporative condensing-system. It will cool off, more slowly than will a standard system, since, on stopping, thermosiphonic action is impossible; and it will work well even with a low water-level. As a water system, it is superior to present practice; and, if abused, will improve automatically, becoming a constant-temperature evaporation-system

Relationships between Lubricating Systems and Engine Performance

By T. E. Coleman[1] and J. B. Fisher[2]

Annual Meeting Paper *Illustrated with* Charts, Drawings and Photographs

ABSTRACT

ALWAYS prominent in the thoughts of automotive engineers, the lubrication of an internal-combustion engine presents continuous interest in that characteristic and elusive lubrication difficulties exist which largely baffle correction. Many of these difficulties are still existent because, according to the authors, more energy has been expended in correcting diseases of the lubricating system than has been spent in preventing the diseases by original design. When analysis is made of what has been done in the last few years of study on lubrication, it is irksome to realize that we still have to contend with all the former troubles such as oil-pumping or over-lubrication, fuel dilution of the oil supply, lubrication failures under certain conditions of engine operation, excessive wear on engine parts and high maintenance-costs. All these defects do not exist in all engines; but one or more of them are present in most engines, and all of them, as well as some others, exist in some engines that are produced in large quantity.

Certain facts relating to the behavior of lubricating systems are presented, and also the conclusions that have been drawn from observation of systems which vary in their mechanical elements. The conclusions have been checked carefully by tests on many different types of engine, and the test results have been strengthened by close observation of the field operation of automotive engines.

All variations and combinations of the splash and of the force-feed lubricating-systems are classified under the term "crankcase systems." The fresh-oil system differs fundamentally in that it feeds no appreciable surplus to the bearing surfaces, and the slight surplus that may be provided as a safety factor need not be recirculated. The tests involve two types of fresh-oil system; that is, the "full fresh-oil," providing for the lubrication of all bearing surfaces by small quantities of unused lubricant applied directly to the engine parts, and the "combination fresh-oil and crankcase system," the latter method furnishing fresh oil in minute quantities for cylinder lubrication and recirculated oil for the lubrication of bearings and other surfaces.

Following a statement of the desirability of research in regard to lubrication systems, the hidden relationships existent between lubricating systems and engine operation are discussed, those elements of engine performance that are influenced by lubricating systems being grouped to include maximum power; fuel-consumption; oil-consumption; detonation; and dependability, maintenance and long life. The results of comparative tests made on a six-cylinder 75-hp. engine are presented and explained, together with accompanying illustrations.

THE willingness to present a paper on an engineering subject usually depends upon the author's belief that he has a source of interesting material and that the discussion of the material can be of some benefit to those who are lured by the title into reading the paper. In this case the two authors have had a source of information on engine lubrication that has not been available generally to the members of the Society. It seemed, furthermore, that this material concerned itself chiefly with the mechanical elements of engine lubrication, and that it held interesting information on this phase of the subject which has been given comparatively little attention in the previous discussions of engine lubrication. Therefore, we attempt to reveal in the following text certain facts relating to the behavior of lubricating systems and also the conclusions that have been drawn from the observation of systems which vary in their mechanical elements. So that readers will have the confidence in our material which we hope it deserves, we will state that our conclusions have been checked carefully by tests on many different types of engine, and that our test results have been strengthened by close observation of the field operation of automotive engines.

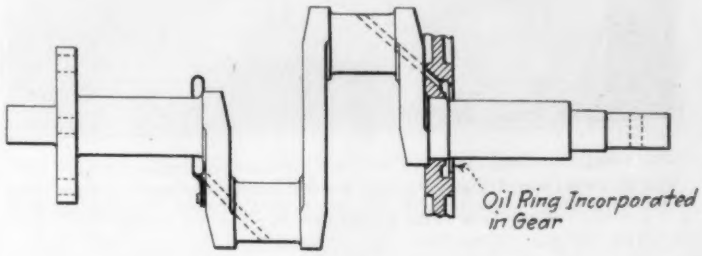

Fig. 1—Oil-Ring Assembly
Details of Two Types of Centrifugal Oil-Ring Are Displayed

This paper is not founded on any one set of tests made to determine prophesied results, nor were most of the tests made to prepare this paper for the members of the Society. The material is rather a collection of data determined by several hundred hours of tests made on more than a dozen engines over a period of 5 years. A few of the tests were made in the field and much material was gained in that manner. Most of the tests were laboratory runs, however, and were made with the approved equipment that is customarily used.

The problem is to present such a mass of material properly, in a manner that will make the picture both clear and interesting. It is planned, therefore, to present in the following text a running account of many of the interesting observations that we have made, and to present such supporting test-data as may seem to be desirable.

Two Classifications for Oiling Systems

If we consider all types of automotive engine, we can name a great variety of oiling systems in general use today. Among these are the conventional and accepted true examples of the splash, force-feed and fresh-oil systems and many combinations of these designs arranged so as to meet the ideas of the different engineering minds that conceived them. It is not necessary to describe the de-

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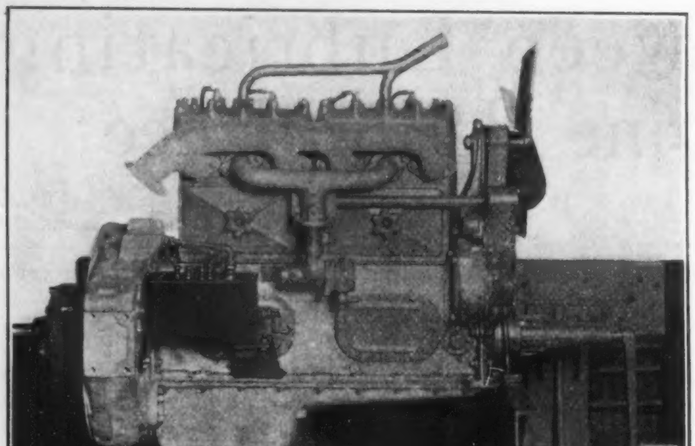

FIG. 2—INSTALLATION OF THE LUBRICATOR MECHANISM
The Photograph Illustrates the Conventional Method of Installing the Lubricator Mechanism on a Four-Cylinder Vertical-Engine When the Full-Fresh-Oil System Is Used

tails of all these systems, because it is assumed that the designs are well understood. We can indicate here, however, what we believe to be the fundamental differences in characteristics of these mechanical arrangements for oiling engines.

The splash and the force-feed systems, including all variations and combinations, can be classified together under the term "crankcase systems." They employ the method of supplying to all engine parts a large quantity of oil, the surplus from which is returned to the crankcase sump and then recirculated in the same manner again and again. In all the variations of these systems, used oil is the medium of lubrication.

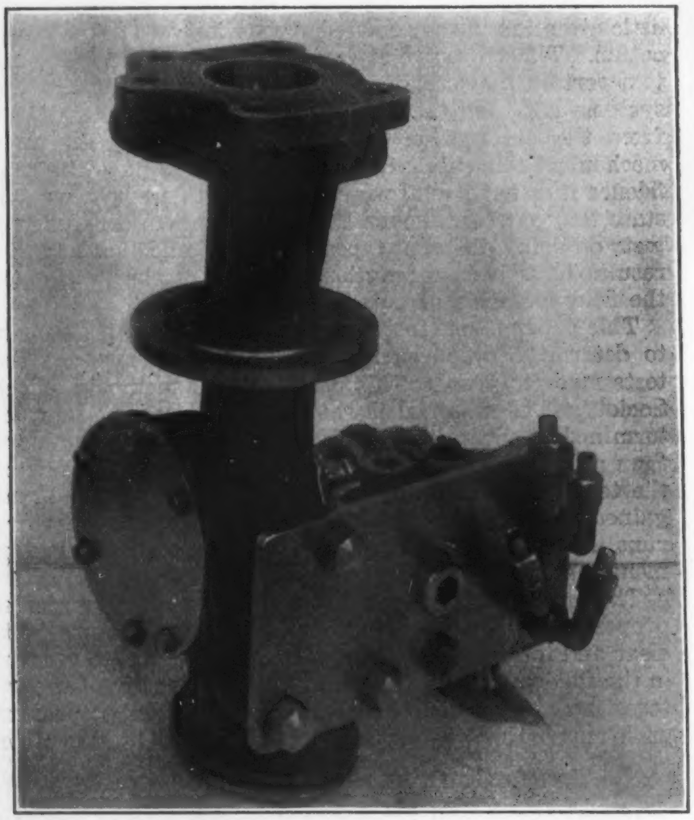

FIG. 3—LUBRICATOR ASSEMBLY
The Gear-Pump and the Fresh-Oil Pump Can Be Mounted on One Assembly Located inside the Crankcase and Driven from the Camshaft in the Conventional Manner. The Gear-Pump Provides Lubrication for the Bearings and the Fresh-Oil Lubricator Is for Cylinder-Barrel Lubrication. The Gear-Pump Has Its Intake in the Oil Supply in the Sump, but the Fresh-Oil Pump Receives Its Oil through a Tube Connected with a Tank of Fresh Oil Mounted on the Outside of the Engine

The fresh-oil system differs fundamentally in that it feeds no appreciable surplus to the bearing surfaces, and the slight surplus that may be provided as a safety factor need not be recirculated. This is the case in the true fresh-oil system; whereas, it is not strictly true in cases where the method is combined with the splash or the force-feed systems. It is customary in some engines to use fresh oil for cylinder lubrication only and recirculated oil for the bearings, a combination that has produced some of the interesting results which will be discussed in this paper.

While the crankcase systems are well understood as to design and operation, the fresh-oil systems are not so clearly understood and they need a few paragraphs of description so that the reader may have the necessary information upon which to judge many of the statements that will follow. Our tests involve two types of fresh-oil system; that is, the "full fresh-oil," providing for the lubrication of all bearing-surfaces by small quantities of unused lubricant applied directly to the engine parts, and the "combination fresh-oil and crankcase system." This latter method provides fresh oil in minute quantities for cylinder lubrication and recirculated oil for the lubrication of the bearings and other surfaces.

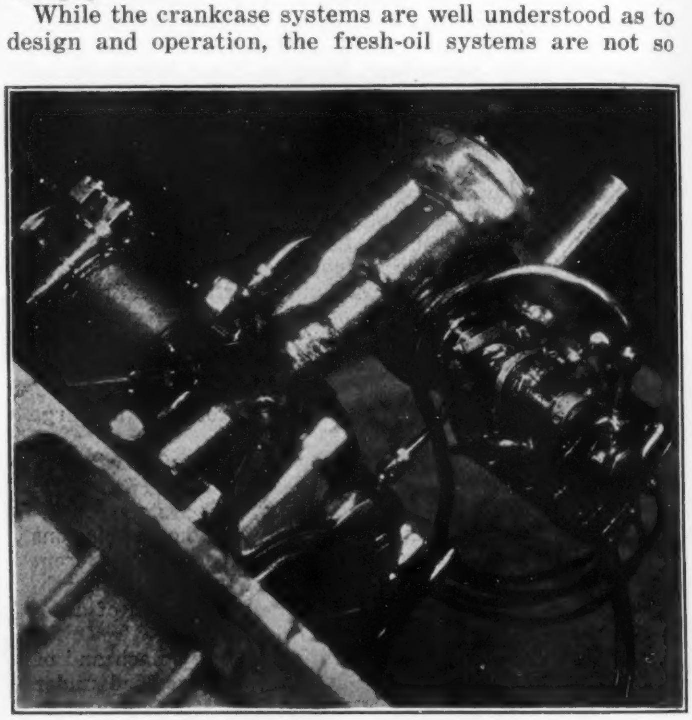

FIG. 4—COMBINATION-SYSTEM LUBRICATOR-ASSEMBLY
The Photograph Shows the Lubricator Assembly for the Combination Fresh-Oil and Crankcase System Mounted in the Crankcase of a Six-Cylinder Engine

When the full fresh-oil system is employed, the installation usually provides a mechanism for metering oil properly and forcing it through leads to the cylinder-barrels, main and crankpin bearings and timing-gears. The oil is injected into each cylinder at a point opposite the first bridge-wall of the piston at the down dead-center position of the piston. An oil-lead carries the lubricant to each main bearing and to a centrifugal ring placed on the crankshaft cheek to throw the oil into the crankpin drilling through which it is carried to the crankpin bearing. The lubricator mechanism is driven from the camshaft so that it operates automatically with the engine speed,

thereby delivering lubricant in quantities that vary directly with the speed of the engine.

The oil-ring assembly is displayed in detail in Fig. 1, and Fig. 2 illustrates a conventional method of installing the lubricator mechanism on a four-cylinder vertical-engine. In this case the lubricator is mounted on the side of the engine in such a position that it can be operated from a horizontal shaft driven from the camshaft. The pumping unit is carried in the tank that serves also as the container for the supply of fresh oil. Such an application as we have just described permits the greatest possible freedom to the investigator who is searching for

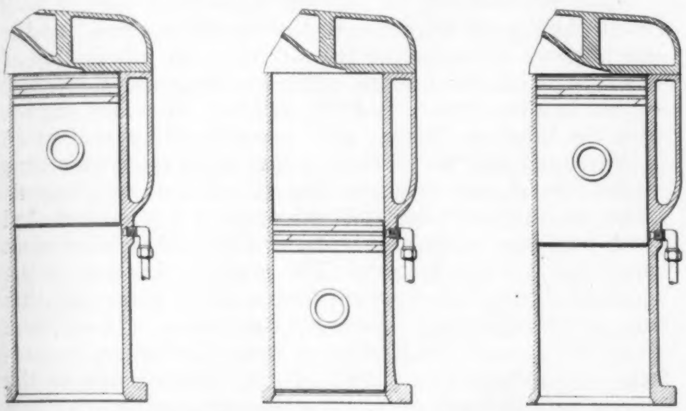

FIG. 5—METHOD OF OIL APPLICATION FOR CYLINDER LUBRICATION
The Location of the Oil-Injection Point for Cylinder Lubrication for the Fresh-Oil System Is Shown. At the Left, the Short Piston Is Displayed in Top Dead-Center Position. The Central and the Right Views Show the Long Piston at Down Dead-Center and at Top Dead-Center Positions, Illustrating That in Such a Case the Oil-Injection Point Is Never Uncovered

accurate data on the actual oil-requirements of the various bearing-surfaces of an engine, and this system has been used in many of our tests. We have also used it on certain engines in direct comparison with crankcase systems to observe the effects that the two characteristically different types of system might have on the operation of a given engine.

We have used in our tests also the combination fresh-oil and crankcase system for comparison and observation. As previously stated, this method is devised to provide the pistons with a fresh-oil seal and at the same time to permit the use of the flood system for bearing lubrication. An engine can be fitted with such a system without altering its appearance, due to the fact that the gear-pump and the fresh-oil pump can be mounted on one assembly located inside the crankcase and driven from the camshaft in the conventional manner. Such an assembly is illustrated in Fig. 3. In Fig. 4, another similar assembly is shown mounted in the crankcase of a six-cylinder engine.

In most of our tests we have placed the greatest stress on cylinder lubrication, for we feel that it needs the most careful attention and we consider that the simple method of oil application which we have been using as standard is acceptable due to its dependability. Therefore, we offer Fig. 5 to give a clear conception of the method used. The piston, in its down dead-center position, stands with its first bridge-wall just opposite the oil-injection drilling in the cylinder-barrel. A slight groove is tooled into the cylinder at the point of oil-injection. It will be apparent that it is desirable to have the oil-distributing groove registering at all times with the oil injection, and such would not be the case if the oil-groove were placed only in the piston. This cylinder groove need not be wider than one-fourth the width of the piston-ring, and its depth can be equal to its width.

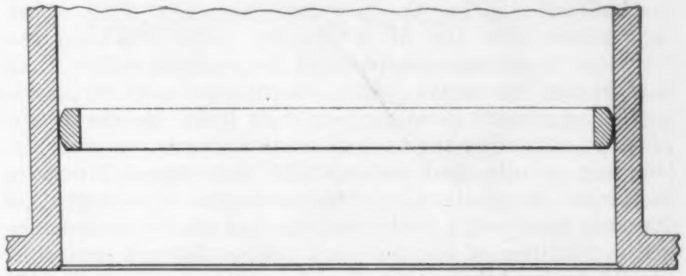

FIG. 6—EFFECTS OF PISTON-RING WEAR
Over-Lubrication Effects Are Exaggerated Still Further Due to the Decreasing Efficiency of the Average Piston-Ring Caused by Both Wearing of the Ring in the Piston-Ring Groove and the Tendency of the Face of the Ring To Round Over as Shown in the Illustration

In some cases it is desirable to have the piston length such that the piston does not at any time uncover the oil-port in the cylinder, although this has been proved unnecessary in the standard designs of automotive engine. We made no effort to time the injection of oil to the pistons, for the oil-impulse is carried over many engine revolutions, and timing is not a desirable feature. Our experience has proved that 5 oil-impulses per 1000 engine revolutions is suitable for good cylinder-lubrication.

RESEARCH ON LUBRICATION SYSTEMS DESIRABLE

Although much good active effort has been expended on lubrication research, the lubrication of an internal-combustion engine possesses even now characteristic difficulties that are elusive from the standpoint of correction. Many of these difficulties are with us today because we have expended more energy in correcting diseases of the lubricating systems than we have spent in preventing the diseases by the original design. When we pause long enough to analyze what we have been doing in the last few years of study, it is irksome to realize that we still have to contend with the old reliable bugbears, such as oil-pumping or over-lubrication, fuel dilution of the oil supply, lubrication failures under certain conditions of engine operation, excessive wear on engine parts, and high maintenance-costs. All these defects do not exist in all engines, by any means; but one or more of them are present in most engines, and all of them and a few extra ones not mentioned exist in some engines that are produced in large quantities today. This prompts one to consider the lines of attack by which we have attempted to improve the situation.

Certainly, the lubricant itself has been given thorough attention, and perhaps more scientific thought and research have been spent on the improvement of lubricants to meet operating conditions than have been spent on the

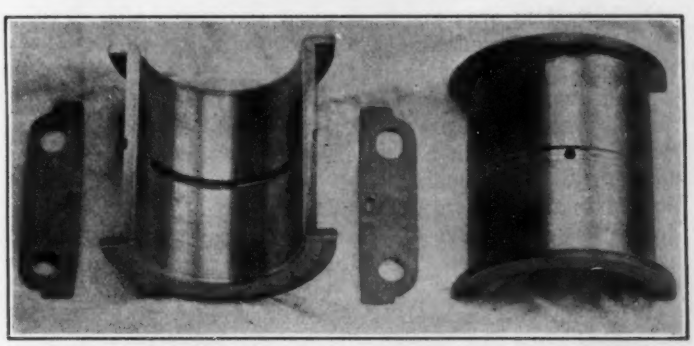

FIG. 7—OIL THROW-OFF FROM CRANKCASE CHEEKS
The Quantity of Oil Thrown-Off from the Crankcase Cheeks Can Be Controlled Fairly Well by the Main-Bearing Construction Shown, Which Is Designed To Prevent the Escape of Oil

methods of utilizing the lubricant properly. Only in recent years have the oil companies been attacking the situation from the standpoint of the systems rather than that of the lubricants. As a result, until recently, automotive engineers have pinned their hopes on the possibility of obtaining the desired corrective results from the blending of oils, and undoubtedly have hoped for more than could be obtained by these methods. This statement does not carry with it the feeling that the improvements in the qualities of oils have not been a distinct contribution to better lubrication, for it certainly is true that if an engine owner today damages his engine on account of poor oil, he can blame only his own poor judgment.

Many Lubrication Troubles Still Exist

No paper on this subject could be complete without a reference to some of the problems encountered in the lubrication of automotive engines. We mention this with the promise that our paper will not fall into too lengthy a discussion of time-worn subjects.

First, when referring to an internal-combustion engine, the motoring public uses the term engine or motor and vaguely associates its lubrication problems with those of a steam engine or an electric motor. Whereas a steam engine or an electric motor merely utilizes power developed by another unit, a gasoline engine both develops and utilizes its own power. It must combine the functions that, in a steam powerplant, are divided among a number of units. It must provide a means of atomizing the fuel, mixing it in the proper ratio with air and distributing it to the various cylinders. It must provide means for compressing the air-fuel mixture to the correct pressure so that it can be converted into power with as high a thermal efficiency as possible. After the fuel is burned, the engine must perform the duties of an ash-conveying system insofar as expelling the residual products of combustion is concerned. Throughout the cycle of its many duties every moving part of the engine must be lubricated thoroughly, without danger of over-lubrication, and although subjected at times to very unfavorable influences in the way of temperatures, dust, excessive speeds, and the bad effects of the water vapor and other elements left in the engine after the fuel is burned.

Lubrication Development

In the early stages of internal-combustion-engine development, the splash system of lubrication met the demands fairly well. The speeds were moderate, the fuels were of good quality and an ample supply of oil embodying the desirable qualities for proper lubrication was available. As the operating speeds were increased it became apparent that, to secure more positive lubrication of the rod and main bearings, some other means than the splash system was required, and the force-feed system gradually superseded the splash system. However, with the abandonment of the splash system, one marked advantage was sacrificed with it. With the splash system, an oily vapor was present in the crankcase which penetrated every part of the case, finding its way to the valve chambers, gear housing and push-rods, and it provided ample, in fact, often too much lubrication, for the cylinder-walls. The value of this oily vapor cannot be denied, as it was an ideal means of lubricating many parts of the engine.

With the advent of the force-feed system, engineers depended upon the throw-off from the crankshaft to lubricate the pistons and cylinders, with leads to auxiliary shafts and in some cases to the timing-gears. With this system, not nearly so much oil is in suspension to lubricate such parts of the engine as the push-rods, valves and gears. Furthermore, the oil thrown-off from the shaft is in relatively heavy drops and is thrown against the interior walls of the crankcase in planes coincident usually with the crankshaft cheeks adjacent to the main bearings. It does not obligingly float around throughout the crankcase as does the oil that the dippers on the connecting-rods beat into a fine mist in the splash systems. In observing engines in operation with the splash and the force-feed systems, we have noticed that a far greater amount of oil exists in suspension in the crankcase with the splash system.

Some engines employing the force-feed system still retain the dip-trough beneath the connecting-rods for the sole purpose of producing the oily mist for lubrication of other parts of the engine. The conventional force-feed system has one other weakness in that, on a new engine, with the bearings fairly tight, a minimum amount of oil is thrown-off to the cylinders, which need oil at this time more than at any time during the life of the engine. Later on, cylinders and pistons acquire a good polished finish and less oil is required for their lubrication than when they left the factory. The greater clearance in the bearings due to wear permits more oil to escape at this time, when really less oil would be desirable. In extreme cases this permits bad cases of over-lubrication, the effects of which are exaggerated still further due to the decreasing efficiency of the average piston-ring. By this is meant both the wearing of the ring in the piston-ring groove and the tendency of the face of the ring to round over, as shown in Fig. 6. A ring worn thus has obviously lost its most valuable asset, that is, its ability to scrape-off surplus-oil on the down stroke, and an examination of rings from engines inclined to pumping oil will often show this wear.

The quantity of oil thrown off by the crankshaft cheeks can be controlled fairly well by the main-bearing construction shown in Fig. 7. It will be noted that the oil-groove in the face of the bearing does not extend into the shim contact-surface. There is a mating groove on the back of the bearing, the groove in the upper and lower halves registering through a hole in each shim. The inner groove on the upper half of the bearing is thus supplied with oil under pressure, but no oil is under pressure at the points where the shims usually seat against the crankshaft, the point where most leakage takes place.

Lubrication of pistons and cylinders on high-speed engines is further complicated by a condition that arises from the nature of the finish of the cylinder-walls. If the walls are not absolutely smooth but contain minute corrugations due to the method of finishing, the rings will be forced away from the cylinder-walls at high piston-speeds. This tendency of rings to collapse permits the hot gases to blow down past the piston-walls, and is detrimental to the lubrication of the piston, cylinder and rings. In engines in which this ring action has been observed, it has been indicated clearly by the gasometer described elsewhere in this paper. The gasometer will rise slowly as the engine speed is increased until the critical speed at which the ring action takes place, when it will rise very rapidly.

Lubrication in Winter

As operation of motor vehicles in cold weather is increasing yearly with the advent of better roads and methods for keeping them open, the problems of winter lubrication have been increased. The particularly harmful effect of the lag that takes place between the time that an engine is started in zero weather and the time that oil is

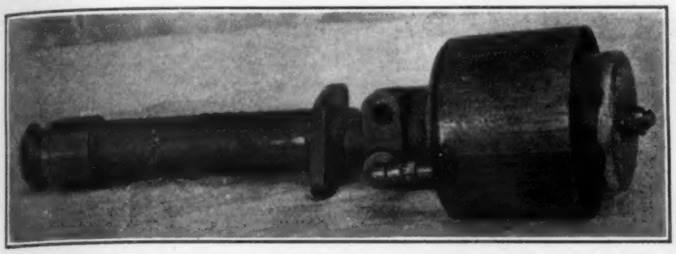

FIG. 8—PREVENTION OF PUMP FAILURE IN COLD OIL
To Prevent the Pump from Drawing in Air and To Force It To Exert a Suction on the Oil Surrounding the Screen, the Construction Shown Is Sometimes Employed. An Air-Tight Bell Is Fitted over the Screen So That Air Cannot Flow through Any Portion of the Screen That Otherwise Would Be Exposed above or near the Oil-Level under the Conditions Described in the Paper

actually thrown to the cylinder-walls has been brought clearly to attention by Frank Jardine in his article on Scuffed Pistons Result from Cold Jacket and Lack of Oil[3] and in a more recent paper on Engine Corrosion, Its Causes and Avoidance[4], and need not be recounted here. The fact that this tardy action of the oiling system is often due to failure of the heavy oil to flow through the pump screen has not been shown so clearly. A conventional gear-pump will draw all the oil from inside a pump screen in a few seconds after starting and, if the oil does not flow through the screen rapidly enough to supply the pump, the pump will suck air when any portion of the screen is near the oil-level. The oil-level in this sense may mean an irregular outline representing the top surface of the semi-fluid oil, usually cupped-out in the vicinity of the pump immediately after starting in cold weather. To prevent the pump from drawing in air and to force it to exert a suction on the oil surrounding the screen, the construction in Fig. 8 is sometimes employed. An air-tight bell is fitted over the screen, so that air cannot flow through any portion of the screen that otherwise would be exposed above or near the oil-level under the conditions already described.

[3] See *Automotive Industries*, July 31, 1924, p. 242.

[4] See THE JOURNAL, December, 1925, p. 605.

MANY HIDDEN RELATIONSHIPS EXIST BETWEEN LUBRICATING SYSTEMS AND ENGINE OPERATION

The few preceding paragraphs have concerned themselves with those apparent manifestations of defective lubrication that all of us have known and have worked over for many years. They deserve a great amount of attention, although they have become somewhat tiresome just as does any companion that clings too tightly for too long a time. Our tests will show methods by which we have overcome these difficulties; and they will indicate that, by rendering these enemies helpless, we have also revealed many hidden relationships between lubricating systems and engine operation.

To eliminate the evils of over-lubrication and dilution

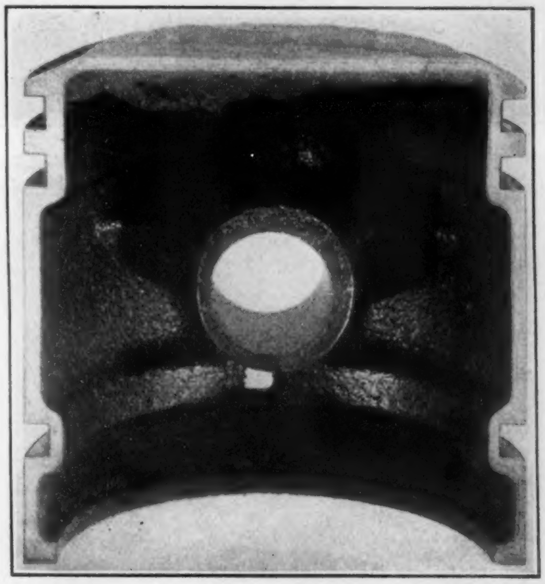

FIG. 9—PISTON-HEAD CARBON-ACCUMULATION
A Typical Case of Under-Side Carbon-Accumulation in Which the Piston Had Become Encrusted to Such a Degree That the Engine Knocked Badly under Even Moderate Loads Is Illustrated

FIG. 10—OIL-BAFFLES IN PLACE UNDER THE CYLINDER-BARRELS
An Effective Set of Baffles Was Installed under the Cylinder-Barrels As Illustrated To Keep the Crankcase Oil Entirely Away from the Cylinder during the Second Set of Runs

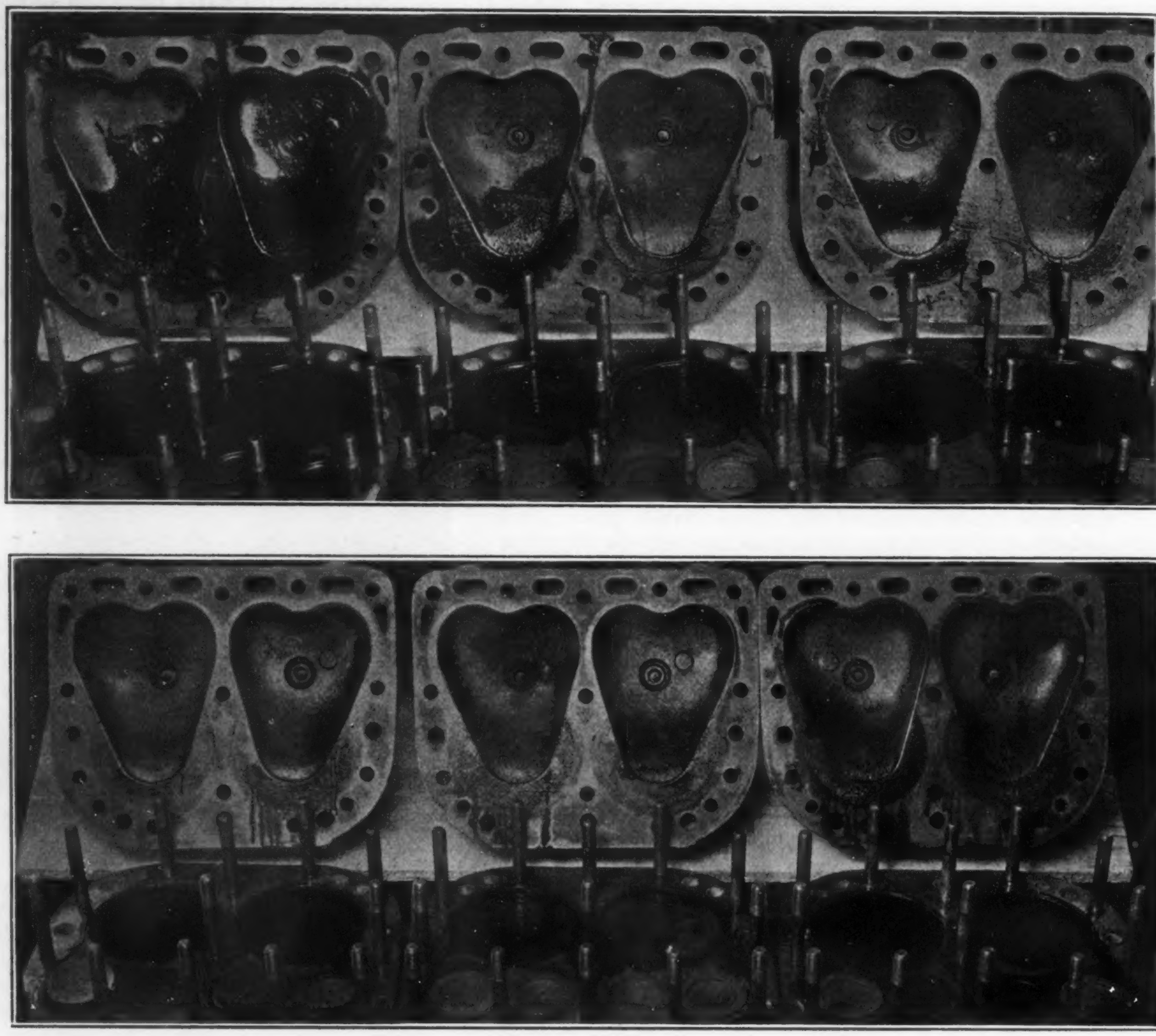

FIG. 11—CARBON ACCUMULATION CAUSED BY OIL ALONE
After a 3-Hr. Run, Idling, with the Crankcase System of Lubrication, the Cylinder-Heads Were Moist with Slight Traces of Hard Carbon Forming and the Tops of the Pistons Were Covered with Wet Black Oil As Shown in the Upper View. This Black Oil Formed in Vertical Streaks on the Cylinder-Walls As Shown Most Clearly on Cylinders Nos. 1 and 4. In the Lower View, Taken After the Same Run with Fresh Oil Only Fed to the Cylinders, the Cylinder-Heads Were Comparatively Dry and the Tops of the Pistons Had a Thin Covering of Clean Oil

of the oil supply, we have proceeded in our test work in such a manner as to make the occurrence of these difficulties impossible. The only way to accomplish this is to provide such small quantities of oil that over-lubrication cannot occur, and to feed to the engine only fresh unused-oil so that dilution cannot enter into the situation. Since the real purpose of the lubricant is to separate the bearing surfaces effectually, it is logical to assume that it is proper to feed to those surfaces only the quantity of oil required for that purpose. We have determined, for example, that a 4½-in. piston needs less than 15 drops of fresh oil per min. when operating under full load at 1500 r.p.m. If the proper mechanism is used to feed oil to the pistons in such quantities, it is safe to assume that the surplus will be very small. The crankpin bearings of a 45-hp. four-cylinder truck-engine operating under full load at a speed of 1000 r.p.m. require not more than 5 drops of fresh oil per min. per bearing.

When these facts are known it is only necessary to proceed with thorough tests of a number of different sizes and designs of engine, employing different types of lubricating system for each engine, to determine the effects that these systems have on engine operation. We have proceeded in this manner over a period of several years, involving data concerning extended runs on many engines. Much of this material has been tabulated to present it to the members of the Society in this paper, so that not only our conclusions but also their conclusions can be drawn from the material.

Our belief holds that one cannot appreciate how extensive these hidden relationships between lubricating systems and engine performance are unless he spends considerable time in tracing them carefully. As he becomes familiar with his subjects he is likely to group those elements of engine performance that are influenced by lubricating systems to include (*a*) maximum power; (*b*) fuel-consumption; (*c*) oil-consumption; (*d*) detonation, and (*e*) dependability, maintenance and long life.

A glance at this list will cause some comment to the effect that it is difficult to determine that engines would display any appreciable variations in these respects if they were equipped with one lubricating system and then another. However, they do vary in performance when such changes are made, and the variations are consistent

enough in the many individual cases to permit us to draw definite conclusions that are supported by the facts in these cases. It will be best to consider the questions under the individual headings.

Maximum Power

The methods of applying oil to an engine can be the cause of appreciable variations in the maximum power that the engine is capable of delivering. Consider Table 1, which gives the maximum-power readings of four engines, each of which was tested with two fundamentally different oiling-systems. One column presents the maximum-power readings when the crankcase system was in operation, and the other column reveals the increases in the maximum power when the fresh-oil system was installed. These increases were not caused by the same elements in all four engines, although over-lubrication can be held responsible as the underlying cause in each case. In Engines Nos. 1, 2 and 3, the crankcase system permitted too great quantities of oil to reach the combustion-chambers, in this way causing the oil to interfere with the fuel charge that the carbureter had metered out for the best full-load performance. Without question such interference does occur, and the fact is easily demonstrated in some engines.

TABLE 1—MAXIMUM-POWER COMPARISONS[5]

Engine Numbers	Test Numbers	Crankcase System, B.Hp.	Fresh-Oil System, B.Hp.
1	70 and 71	25.10[a]	29.10
2	47 and 49	26.80	29.60
3	17 and 29	27.25	35.75
4	80L and 80B	31.90	36.11

[5] In the case of each engine, the oiling system only was changed.

[a] The difference in power readings in the case of engine No. 1 was due to over-lubrication when the crankcase system was in operation.

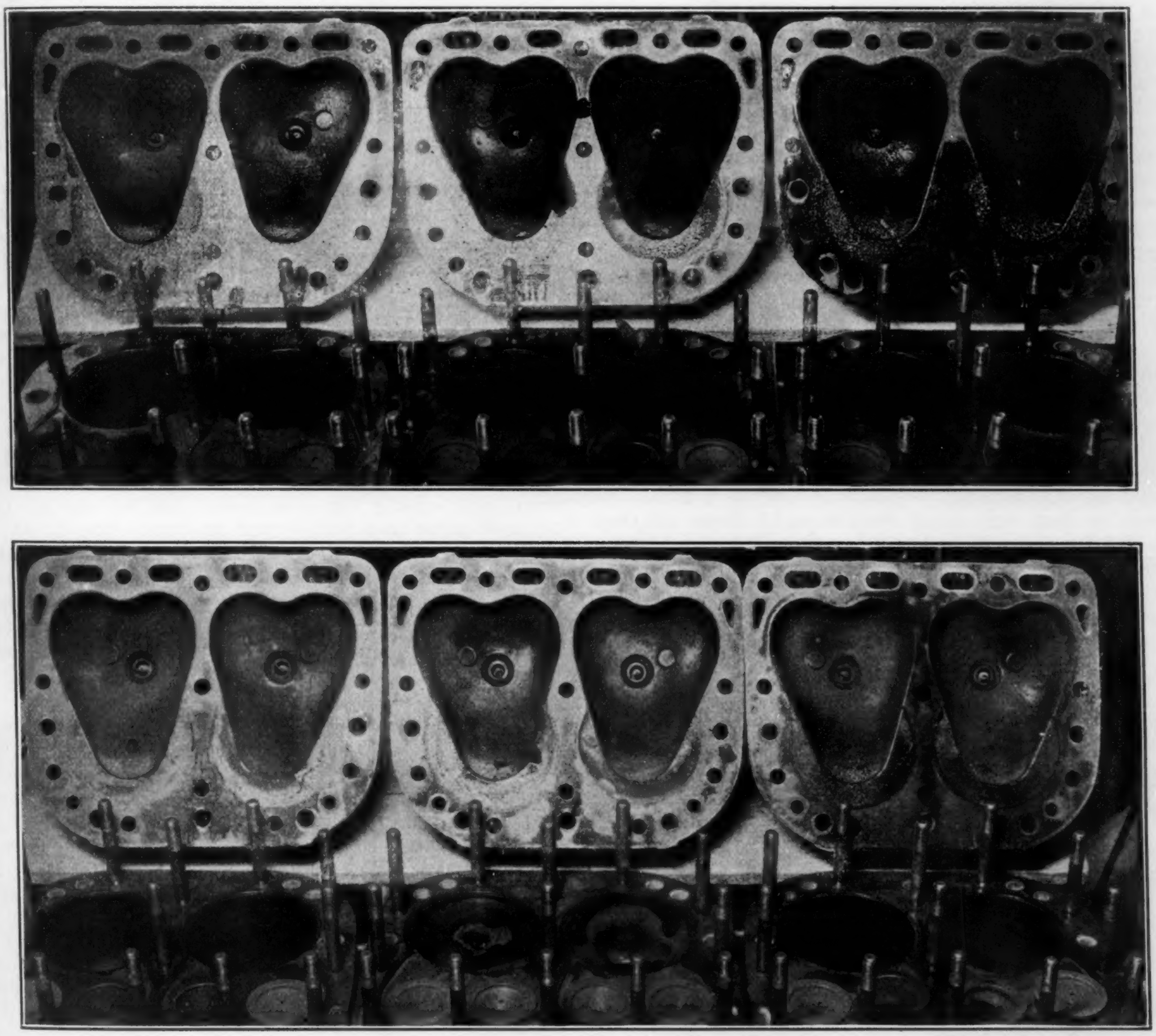

Fig. 12—Carbon Accumulation Caused by Oil Alone

As Illustrated in the Upper View, the Additional 3-Hr. Run at One-Fifth Load Shows That Over-Lubrication Is Still at Work with the Crankcase System, Permitting Some Moisture in the Cylinder-Heads and a Covering of Black Oil on the Piston-Tops, Which Reveal a Half-Dry Spot on No. 3 Which Is Indicative of Hard Carbon in the Making. After Similar Runs with the Fresh-Oil System, All Surfaces Are Dry As Shown in the Lower View, and This Is Especially Evident from the Appearance of the Piston-Tops Which Are, for the Most Part,Clean Enough To Show the Color of the Aluminum. The Oil-Film on the Cylinder-Barrels Does Not Have the Black Streaks That Are Apparent After the Crankcase-System Run and the Carbon Accumulation Is Less

TABLE 2—EXTRACT FROM THE LOG SHEET OF ENGINE TEST NO. 72

Time	Speed, R.P.M.	Load, B.Hp.
11:00	550	29.15
11:05	550	25.11[b]
11:10	550	26.65
11:15	550	27.31
11:20	550	27.31
11:25	550	28.23
11:30	550	28.60
11:35	550	28.93
11:40	550	29.15

[b] This drop in power occurred when the oil-level was raised, permitting the rods to dip. Excess oil was splashed into the cylinders and caused interference in the combustion-chamber. As the oil-level lowered, the power gradually returned.

The results of such a demonstration are given in Table 2, which presents an extract from the log sheet of a test on an engine, great numbers of which are sold each year. This engine possesses a lubricating system that provides, in addition to proper means for cylinder and for bearing lubrication, a supplementary provision that is intended to be a safety factor for crankpin bearings. It is nothing more than an opening in the crankcase into which the operator is instructed to pour a quantity of oil each day to raise the level of the oil to a point that will permit the rod bearings to dip and splash. When this is done, the power of the engine drops immediately as shown in Table 2, and the power does not return to normal until enough oil has been burned so that the level has been lowered to a point below the lowest point of travel of the rod bearings. This same interference exists in many engines that are produced in great quantities today.

Engine No. 4 in Table 1 shows a power variation that is traceable to a different cause. This is a case of tight pistons that permit the engine to produce only about 85 per cent of the true power-rating. The cause of the tight pistons was over-lubrication which had driven the builder to every conceivable remedy for oil-pumping. In view of the fact that this engine was of a horizontal type, oil-pumping with the flood system was acute, and extremely tight-fitting pistons were used as a means of combating the difficulty. When the oiling system was altered so that only small quantities of fresh oil were provided for the cylinders and bearings, the pistons were given the correct amount of clearance with the result that the power of the engine was increased more than 16 per cent. It is true, furthermore, that an engine develops more power when the cylinders and pistons are provided with a good fresh-oil seal. This is apparent to any driver of an automobile when he has the old oil drained from his engine and has new oil substituted. A system that will provide such a seal at all times has a decided effect upon the ability of the engine to produce a high maximum-power.

Fuel-Consumption

The advantages in fuel economies that it is possible to obtain by altering oiling systems are seldom great in any one case, but they are usually worth striving for. When an engine is designed with proper piston-clearances, and with piston-rings that are not severely tight in the cylinders, it has a chance to operate freely and to show a favorable fuel-economy. If it is provided with a good oil-seal between piston and cylinder, and if the fuel charge is not subject to interference by the lubricant, the engine should show good fuel-economy readings. The comparisons made in Table 3 illustrate that fuel economies are consistently better when the lubricant is under proper control. These readings were taken during those same tests that are referred to in the maximum-power comparisons, and it will be seen that those engines displayed not only greater power but also cheaper power when the oiling systems were altered.

TABLE 3—FUEL-ECONOMY COMPARISONS[a]

Engine Numbers	Test Numbers	Crankcase System, Lb. Per B.Hp.-Hr.	Fresh-Oil System, Lb. Per B.Hp.-Hr.
1	70 and 71	0.927	0.911
2	47 and 49	0.876	0.784
3	17 and 29	0.834	0.789
4	80L and 80B	0.880	0.830

[a] In the case of each engine, the oiling system only was changed to obtain comparative readings. All readings are based on the total amount of fuel used during 4-hr. full-load runs.

In all these cases, we are dealing with clean engines and, while the improvements in fuel readings are not startling, they are substantial and would no doubt appear even more favorable if the comparison could have been made after the ravages of service had had opportunity to assert themselves. It has been interesting to us to note that these improvements have been consistent in all cases of comparative tests.

Oil-Consumption

So many disputed elements enter into computing oil-consumption in conventional automotive engines that it is difficult to find agreement on any basis for comparing the oil-consumption of various types of oiling system. First, we must determine what any one person may mean by oil-consumption; that is, whether he acknowledges that the consumption of oil in an automotive engine is only the quantity that actually disappears during engine operation, or that which would be used if the operator made a practice of draining the crankcase as often as he should to obtain the best results. Although records have been kept in the field in many instances, it is safe to say that few engineers will venture a definite statement as to the quantity of oil that an engine should use under any given conditions. When crankcase flood-systems are employed, the results vary so greatly even on a number of engines of exactly the same model that we scarcely know what to state as a proper and moderate figure. On the other hand, if the oil is controlled properly so that a surplus of oil is not fed to the engine, the oil-consumption can be reduced to a certainty. For example, we know that a four-cylinder 45-hp. engine can be operated for 8 hr. at full speed and full-load on 2 qt. of oil, but this same engine operating in trucking service in the field will use less than 1 qt. of oil.

A typical test-run on a six-cylinder 75-hp. engine reveals that the thousands of automotive engines in service today demand more oil for less load. This one engine can be considered a fair example, because it was operated in this test equipped with a conventional circulating system with pressure delivery through the crankshaft. All the runs were made at an engine speed of 1500 r.p.m. and with the temperatures maintained nearly constant at all times. The results showed that the quantity of oil in the crankcase decreased at the rate of 2 pt. per hr. when the engine was running light. At one-fifth load, the consumption was 1 pt. and 8 oz. per hr.; whereas, at two-fifths load, the consumption per hour dropped to 1 pt. and 3 oz. The full-load run showed that at full power the engine uses only 8 oz. of oil per hr., or 25 per cent of the consumption required at no load.

This same engine was next equipped with a fresh-oil system for cylinder lubrication, retaining the flood system for the bearings but providing baffles under the

cylinder-barrels to keep the circulated oil away from the cylinders and pistons. The pistons required 8 oz. of oil per hr., at an engine speed of 1500 r.p.m. and, of course, this quantity did not vary from idling to full load due to the fact that the quantity of oil delivered to the engine depends directly upon the engine speed. With such a system, it is possible to compute accurately just the quantity of oil that will be used under any given speed-conditions, and any number of engines can be produced and sent into the field with the knowledge that all of them will show identical oil-consumption figures in any given service. It is necessary to know only the number of engine revolutions per mile to determine the oil mileage for any car having an engine so equipped.

Detonation

Some doubt always exists as to the degree in which lubrication can be charged with the creation of detonation. We realize, of course, that lubrication is only one of the many causes of this irritating engine-performance, but it is a major cause in some instances. We had as a subject for a set of tests a four-cylinder 35-hp. engine that was a good example of how badly an engine can knock. It did not carry high compression, but it had a splash oiling-system that provided a great excess of oil to the cylinders. In the initial tests we took fuel readings, observed oil consumption and all other factors of interest, and we tried to gage as well as possible the intensity of the "ping" so that we might compare it in later tests after altering the lubricating system. In altering the system, we provided that no excess delivery of oil to the cylinders would occur by eliminating the splash system and providing each bearing and cylinder with only a few drops of fresh oil per minute. No other change was made on the engine, nor was the grade of fuel or oil changed. The engine performed in a much improved manner in all respects, and the ping disappeared entirely. The improvement can be attributed in part, at least, to lack of interference with the fuel charge in the combustion-chambers. It seems logical to assume that the presence of a substantial quantity of lubricating oil in the combustion-chambers at the time of combustion can have

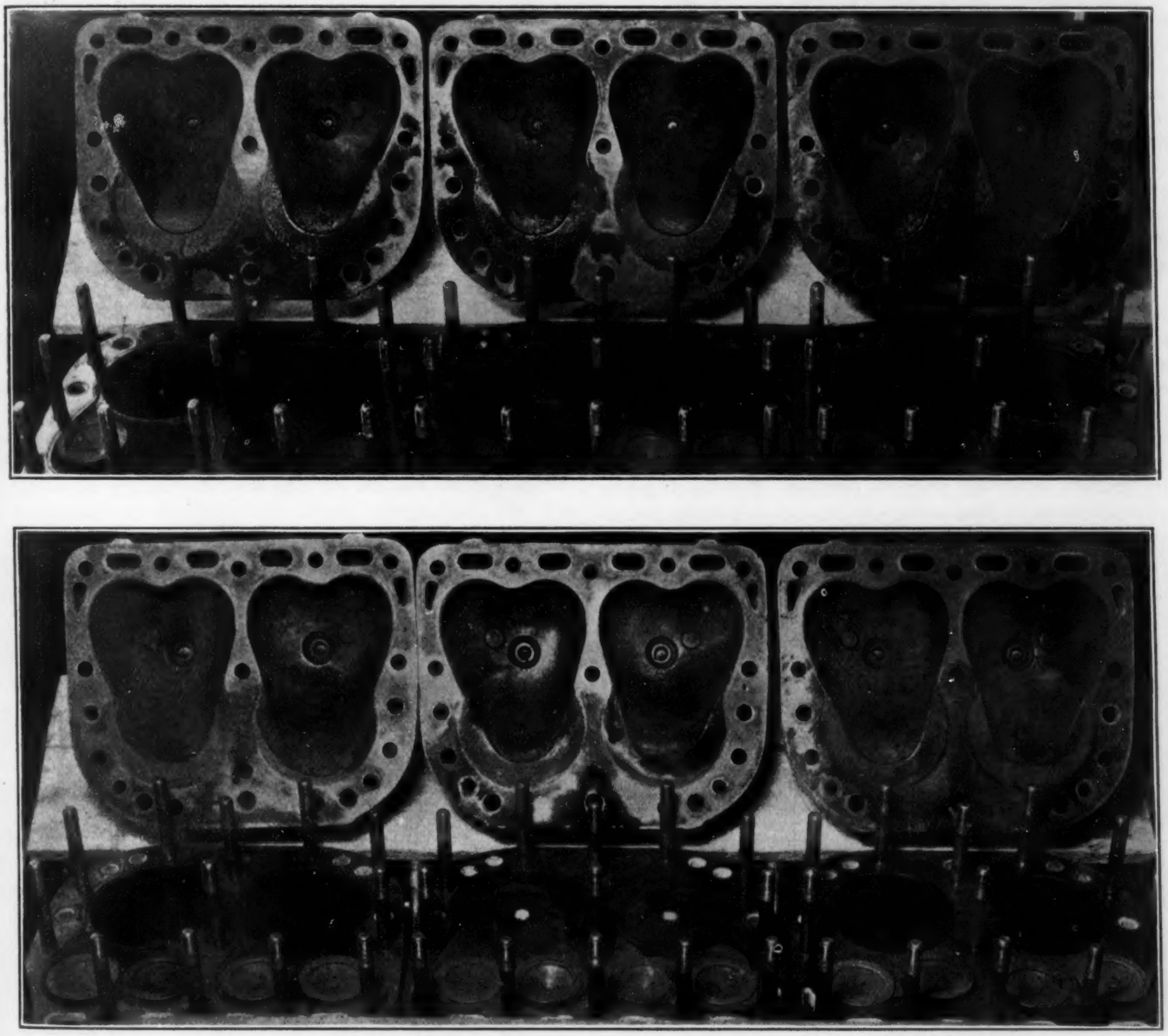

Fig. 13—Carbon Accumulation Caused by Oil Alone
The Hard Carbon That Forms As the Result of Over-Lubrication and Heat Begins To Be Apparent Following 6 Hr. of Two-Fifths-Load Operation. The Carbon Crust Begins To Become Evident on Both Pistons in the Upper View and the Same Sort of Covering Appears to a Degree on the Cylinder-Heads. This Condition Should Be Compared with the Clean Piston-Tops and Cylinder-Heads Shown in the Lower View, Which Pictures the Engine After a Similar Run but with the Fresh Oil for Piston Lubrication

somewhat the same effect that low-grade fuels have in creating detonation. Furthermore, it is probable that in this particular engine the cool fresh-oil had a tendency to cool the center of the piston better and in that way to reduce the cause of "ping."

In another way, defective lubrication can cause detonation; that is, by carbon accumulation in the combustion-chambers and on the under sides of the piston-heads. In some engines the accumulations in the combustion-chambers are excessive while very little or no carbon is deposited under the piston-heads. On the other hand, we have observed engines that accumulate great quantities of carbon under the piston-heads in short runs, and this carbon is continuously broken off and dropped into the crankcase, thus forming a sludge. Of course, the carbon will cause "ping" when it is present in the combustion-chamber, and it will produce the same trouble when it accumulates under the piston-heads because it prevents the proper radiation of heat from the center of the piston-heads. Fig. 9 illustrates a typical case of under-side carbon-accumulation in which the piston had become encrusted to such a degree that the engine knocked badly under even moderate loads.

Dependability, Maintenance and Long Life

The conscientious car-owner probably is more concerned in the oil supply of the engine than in any other factor governing the operation of his car. Whether he has paused to analyze the problem or not, he is conscious of the fact that the dependability, the cost of maintenance and the length of life of his machine depend upon the oil supply. Effectiveness exists, however, only in his ability to provide a good oil supply to permit the lubricating system to do its best. The effectiveness of oiling systems in producing results that will provide unfailing service at a low cost for a long period differ.

For dependability, the mechanism must be rugged and the system should provide the lubricant quickly as the engine starts, regardless of temperatures or other field conditions. For low maintenance-costs, the system

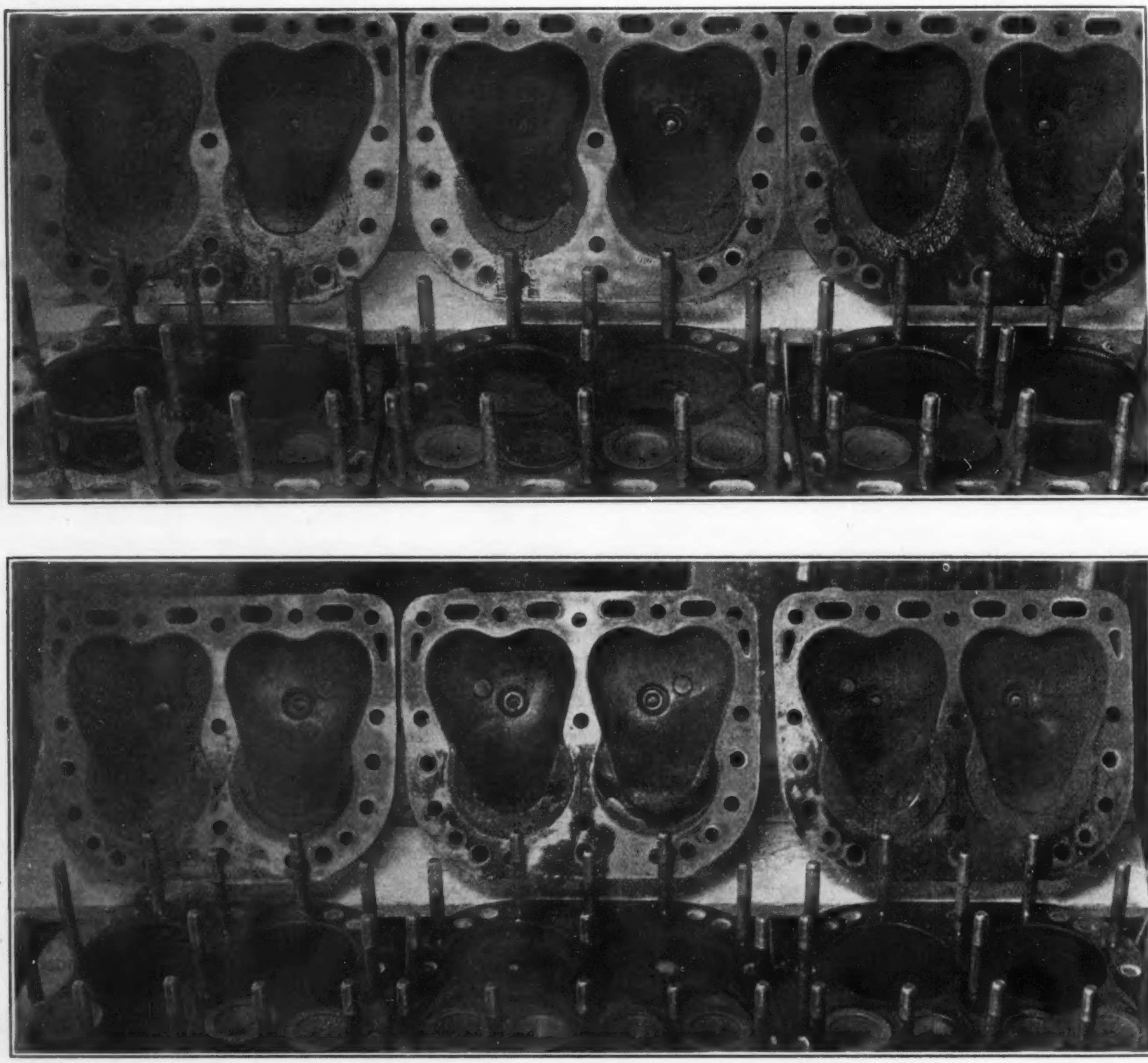

Fig. 14—Carbon Accumulation Caused by Oil Alone

The Views Shown Were Taken After an Additional Run of 6 Hr. at Two-Fifths Load. The Comparisons Are Similar to Those for the Previous Run, with the Carbon Accumulations Appearing in Intensified Form. The Condition of the Combustion-Chambers As Shown in the Lower View Indicates That Practically No Carbon Accumulation Occurred with Fresh Oil, This Being Further Indicative That the Fuel Has Not Been the Cause of Carbon Formation. The Carbon Accumulation Shown in the Upper View, in the Tests with the Crankcase System, Can Be Attributed Entirely to Excess Lubrication

should be dependable and at the same time well arranged to avoid those irritations produced by over-lubrication. Long life depends upon the proper oil-seal for all the bearing surfaces, and the effectiveness of the oil-seal depends upon the quality of the lubricant at the time that it is delivered to the pistons and the bearings. In this respect, we have found that the pistons and cylinders need the most effective provision possible for receiving the correct quantity of good oil unfailingly, for they are subject to conditions that are much more severe than those which govern the service of bearings.

Results of Comparative Tests on a Six-Cylinder 75-Hp. Engine

It was felt desirable for the purposes of this paper to make a series of tests on a modern heavy-duty six-cylinder engine so that we would be in position to display by photographs and charts many interesting phases of engine performance which have a bearing on the contentions that have been made in this paper. Therefore, we prepared such an engine in such a way that it could be put through certain definite dynamometer-runs with a conventional crankcase circulating-system of lubrication, and the same tests repeated later with the engine equipped with the combination fresh-oil and circulating system having provision for the lubrication of the cylinders by small quantities of fresh oil without interference from the crankcase oil-supply. The lubricator assembly was that illustrated in Fig. 4, in which the gear-pump provided bearing lubrication and the fresh-oil pump furnished to the cylinders fresh oil drawn from a supply located outside the crankcase. To keep the crankcase oil entirely away from the cylinders in the second set of runs, we installed an effective set of baffles under the cylinder-barrels as illustrated in Fig. 10. The fresh oil was injected onto the pistons in the manner displayed earlier in Fig. 5.

The tests planned for each system were in each instance at an engine speed of 1500 r.p.m. and for (*a*) 3 hr. idle; (*b*) 3 hr. at one-fifth load; (*c*) 12 hr. at two-fifths load, and (*d*) 1 hr. at full load. It was provided that all engine adjustments should remain unchanged for all runs and that the grades of fuel and oil should be the same. The purpose was to obtain a direct comparison for the two systems for the following elements in the performance of the engine:

(1) Carbon accumulation in the combustion-chambers, by photographs
(2) Oil-consumption
(3) Temperatures of the crankcase oil
(4) The escape of gas into the crankcase
(5) Maximum-power comparisons

By preparing our apparatus with particular care, we were able to finish all these runs within a few days' time, despite the necessity of removing the cylinder-heads several times to photograph the combustion-chambers. These photographs proved to be interesting in their demonstration of the amount of carbon accumulation that can be caused by oil alone. The results are illustrated in Figs. 11, 12, 13 and 14, in each of which we show the relative condition of the combustion-chambers with the two systems after each run was completed.

After a 3 hr. run, idling, with the crankcase system of lubrication, the cylinder-heads were moist with slight traces of hard carbon forming, and the tops of the pistons were covered with wet black oil, as shown in the upper view of Fig. 11. This black oil formed in vertical streaks on the cylinder-walls as shown most clearly on cylinders Nos. 1 and 4. These conditions are evidences

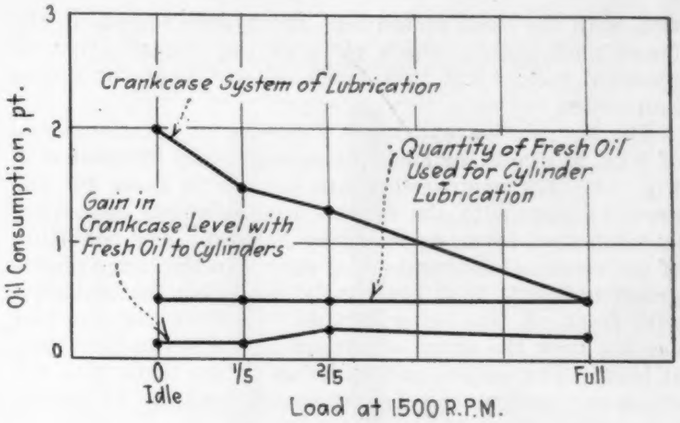

FIG. 15—CRANKCASE OIL CONSUMED PER HOUR
The Chart Presents Accurate Data on the Disappearance of Crankcase Oil in the Case of a Six-Cylinder 75-Hp. Engine

of over-lubrication such as occur when an engine is used as a brake on a down grade. Compare this photograph with that taken after the same run with fresh oil only fed to the cylinders, and reproduced as the lower portion of the same illustration. The cylinder-heads were comparatively dry and the tops of the pistons had a thin covering of clean oil.

The additional 3 hr. at one-fifth load shows that over-lubrication is still at work with the crankcase system, permitting some moisture in the cylinder-heads and a covering of black oil on the piston-tops, which reveal a half-dry spot on No. 3 that is an indication of hard carbon in the making. After similar runs with the fresh-oil system, all surfaces are dry; and this is especially evident from the appearance of the piston-tops which are, for the most part, clean enough to show the color of the aluminum. The oil-film on the cylinder-barrels does not have the black streaks that are apparent after the crankcase-system run. Note, also, that the carbon accumulation is less. The result of this run is shown in Fig. 12.

The hard carbon that forms as the result of over-lubrication and heat following 6 hr. of two-fifths-load operation begins to be apparent. In Fig. 13, the carbon crust begins to become evident on both pistons in the upper photograph, and the same sort of covering appears to a degree on the cylinder-heads. Compare this condi-

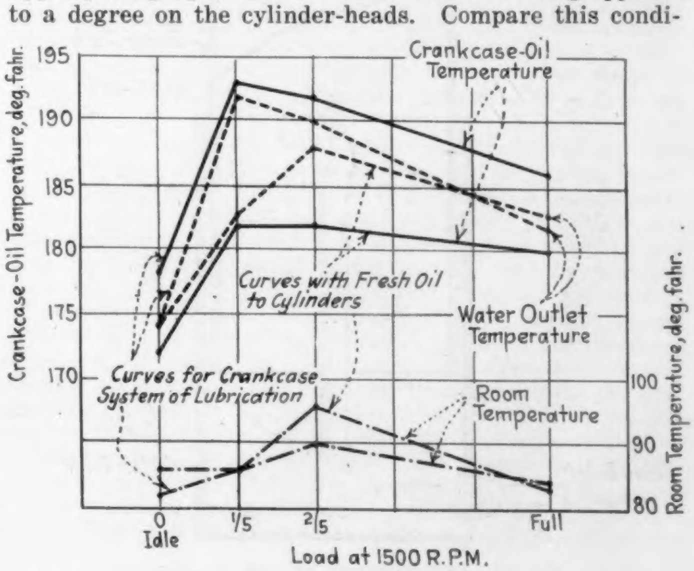

FIG. 16—COMPARISON OF CRANKCASE-OIL TEMPERATURES
In Many Engines, the Temperature of the Crankcase Oil Will Tell a Story of Oil Deterioration. The Contact of Oil with the Extremely Hot Cylinder and Piston Surfaces Raises the Crankcase-Oil Temperatures As Shown

tion with the clean piston-tops and cylinder-heads in the lower photograph, which pictures the engine after an identical run except that fresh oil was used for piston lubrication.

The last photograph taken followed an additional run of 6 hr. at two-fifths load, the results being illustrated in Fig. 14. The comparisons are similar to those for the previous run, with the carbon accumulations appearing in intensified form, as would be natural. The condition of the combustion-chambers as shown in the lower photograph indicates that practically no carbon accumulated with fresh oil, this being further indicative that the fuel has not been the cause of carbon formation in this case, at least. The carbon accumulation in the tests with the crankcase system can be attributed entirely to excess lubrication.

Oil-Consumption Varied Greatly

The oil-consumption figures for these tests were given in the earlier section of the paper under the heading "Oil Consumption," but the chart in Fig. 15 can be referred to here as an interesting picture of accurate data on the disappearance of crankcase oil. When the force-feed system of lubrication is used, the consumption of oil at any given engine load and speed is due fully as much to bearing as to piston fits, and the oil escape from the main bearings is as important as that from the rod bearings. This contention is well proved in Fig. 10. An examination of this photograph reveals six distinct bright-lines on the baffles, which represent the lines of contact of escaping oil with the surface of the baffle. Each line represents an oil leak directly below the line, and two of these bright indicators are produced by the oil that escapes from the ends of the main bearings and follows the cheeks of the crankshaft, from which it is thrown against the baffles. If the baffles were not in place, each of the three cylinder-barrels would be fed by three streams of oil thrown from the shaft.

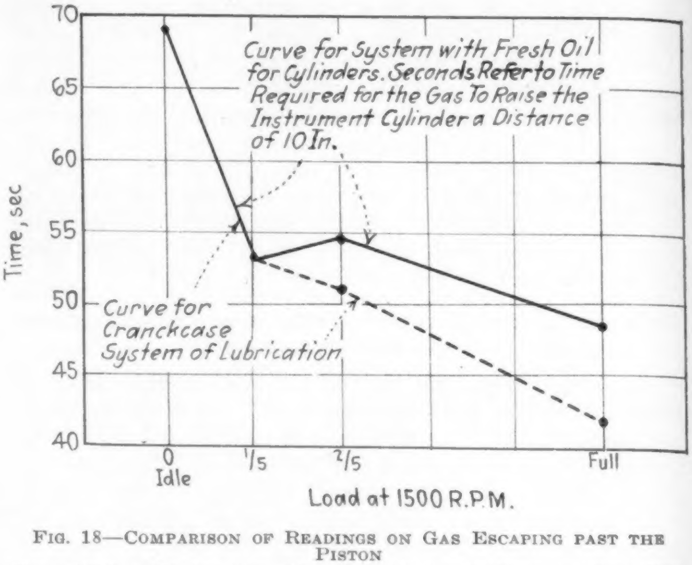

Fig. 18—Comparison of Readings on Gas Escaping past the Piston

The Chart Indicates the Variations in the Volume of Gas That Escaped past the Pistons with the Two Types of Oiling System. While No Variation Was Noticed at the Light Loads, the Variation at Two-Fifths Load and at Full Power Was Perceptibly in Favor of the Fresh-Oil Seal

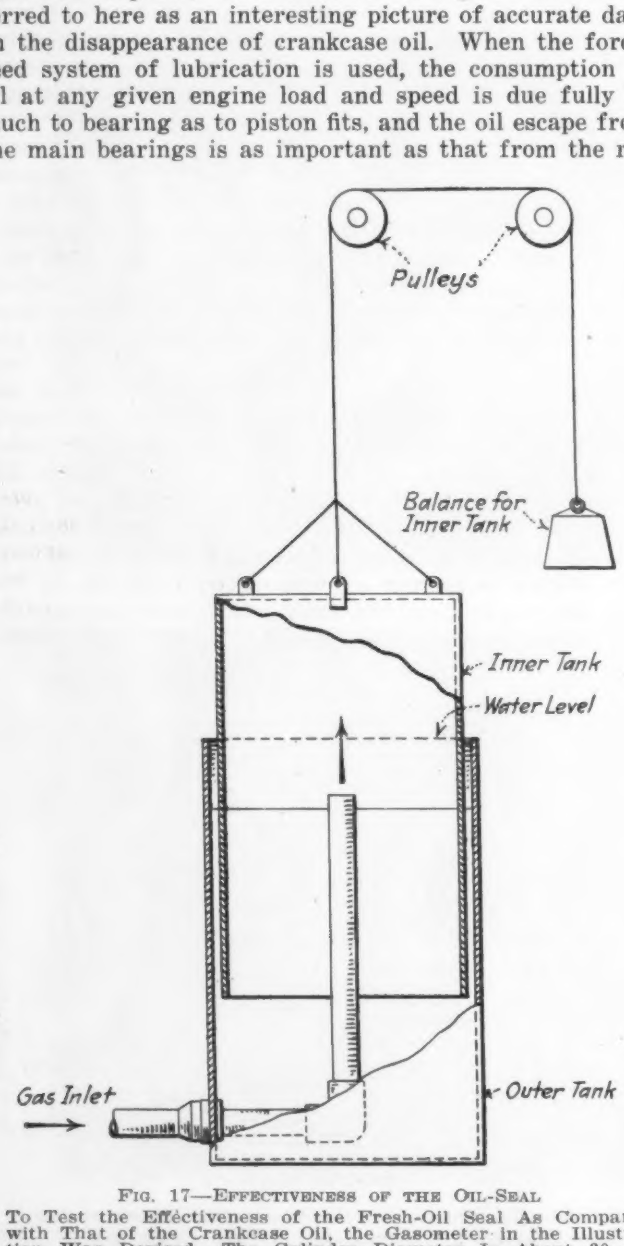

Fig. 17—Effectiveness of the Oil-Seal

To Test the Effectiveness of the Fresh-Oil Seal As Compared with That of the Crankcase Oil, the Gasometer in the Illustration Was Devised. The Cylinder Diameter Is About 20 In. and the Readings Were Taken on the Basis of the Time Required for the Crankcase Gas To Raise the Sealed Cylinder a Distance of 10 In.

After such a demonstration, we need not be surprised to find, as we have in this case, that this six-cylinder engine consumes 2 pt. of oil per hr. without baffles; whereas, the oil-level remains practically constant when the baffles are in place. To be accurate, the chart shows that the oil-level increased during each hour that the engine was operated with baffles, and this increase was due, of course, to the descent of some of the fresh oil that was fed to the cylinders at the rate of 8 oz. per hr.

Temperatures of the Crankcase Oil Were Affected

The temperature of the crankcase oil will tell a story of oil deterioration in many engines. The contact of oil with the extremely hot cylinder and piston surfaces raises the crankcase-oil temperatures as shown in the chart of Fig. 16. While the oil showed a temperature only a few degrees higher when the baffles were not in place to keep it from the cylinder-walls, it will be understood readily that even this rise in temperature of the main body of the oil supply indicates extremely high temperatures for the portions that come into contact with the hot surfaces. The fact that these quantities in suspension are only a small proportion of the total oil-supply at any one time accounts for the fact that a small temperature-rise can indicate an extremely high temperature for the oil at the time of contact. Such temperatures are bound to have an unfavorable effect upon the oil in a comparatively short time, and we believe that our comparison of many samples indicates that the effect is much more unfavorable than is generally realized.

The escape of gas into the crankcase may also exert an influence on crankcase temperatures, as well as an unfavorable influence in causing dilution. To test the

effectiveness of the fresh-oil seal as compared with that of the crankcase oil, we prepared a gasometer that is very simple, as is shown by the diagram in Fig. 17. The cylinder has a diameter of about 20 in., and our readings were taken on the basis of the time required for the crankcase gas to raise the sealed cylinder a distance of 10 in.

The chart in Fig. 18 indicates the variations in the amount of gas that escaped past the pistons with the two types of oiling system. While no variation whatever was noticed at the light loads, the variation at two-fifths load and at full power was perceptible and in favor of the fresh-oil seal. In all these runs, each piston received only 11 drops of fresh oil per min. at an engine speed of 1500 r.p.m., and the results of these observations, as well as other readings, indicate that the oil-seal was good even with such a small quantity being delivered.

The maximum-power readings were a further indication that these small quantities of oil were providing the desired oil-seal, for the maximum power of which the engine was capable at 1500 r.p.m. was about 5 per cent greater with the fresh-oil system of lubrication. This result was in line with the results that have been obtained in many engines, and is shown in Fig. 19.

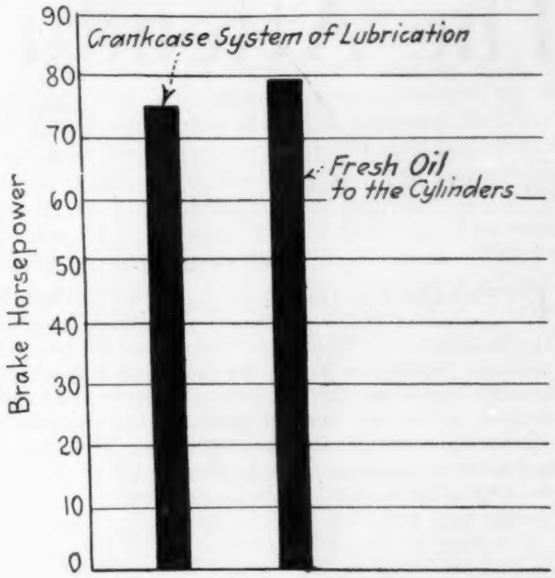

FIG. 19—MAXIMUM-POWER COMPARISONS
In the Case of This Six-Cylinder 75-Hp. Engine, the Maximum-Power Readings Were a Further Indication That the Small Quantities of Oil Were Providing the Desired Oil-Seal, for the Maximum Power of Which the Engine Was Capable at 1500 R.P.M. Was About 5 Per Cent Greater with the Fresh-Oil System of Lubrication

Lubricating systems have many elements that, of course, we have not even touched upon in this paper. We have presented no material on such subjects as oil-filters, air-cleaners, details of oil-pump mechanism, and many other elements, concerning which both lack of information and lack of space did not permit discussion. We have tried merely to put into readable form a mass of material that would be of interest to the members of the Society. We feel confident enough in the value of this material to hope that most of the readers have found in the paper some thoughts on lubrication that are new to them and, perhaps, an answer to some puzzling observations that they may have made in the course of their own experiences.

TRACTOR IN AGRICULTURAL PRODUCTION

In a review of the situation of the farm-machinery industry in this Country which appears in *The Guaranty Survey*, published by the Guaranty Trust Co. of New York, it is remarked that the advent of the gas internal-combustion-engine tractor is undoubtedly the most important development in agricultural machinery, both for the industry and the farmer, since the introduction of the twine binder in 1880. After much costly experimenting in the first decade of this century the tractor was successfully launched on a commercial scale at the beginning of the second decade. By 1914, however, the value of tractors and tractor engines had arrived at only 7 per cent of the total production of agricultural machinery. The term "tractor engines" has reference to the comparatively small number of steam tractors. By 1919 the value of tractors produced rose to about one-third of the total, and reached the high level of 37 per cent in 1920. The value of tractor production in 1919 was almost 10 times that of 1914. The number of tractors produced in this Country rose from about 20,000 in 1915 to nearly 315,000 in 1919, or an increase of approximately 1470 per cent in a period of 4 years.

Although the demand for tractors was very sharply reduced by the prolonged agricultural depression, this type of implement has continued to represent the largest item among the various classes of farm machinery. A temporary overproduction in the tractor industry, however, was indicated by the fact that, although the volume of production in 1921 was only one-third that of 1920, output was still considerably in excess of sales. The value of production in 1922 was about the same as in 1921. The year 1923 saw an increase of about 80 per cent in tractor production, but the year's total was only about one-half of that for 1920. Although 1924 showed a recession in tractor production, sales increased by nearly $8,000,000.

The increased demand for tractors has been the most striking feature of the recent revival in the farm-machinery industry. It is estimated that the sales of tractors in 1925 will show an increase of about 65 per cent over those in 1924, as compared with an increase of total sales of from 25 to 30 per cent.

Many tractor builders reported that production in 1925 was considerably behind demand. The outlook for the future is particularly good. In addition to replacement requirements a tremendous potential demand by farmers who have not yet used tractors exists. The census of 1920 gave 3.6 per cent as the proportion of farms in this Country provided with tractors. The percentage varied from 0.2 per cent in Mississippi to 16.3 per cent in South Dakota. Recent figures indicate that the use of the tractor on the farm has increased considerably since 1920. This increase has not been limited to any one section of the country. In Pennsylvania the proportion of farmers owning tractors increased from 2.7 per cent in 1920 to 9.0 per cent in 1925. In Illinois the proportion of farm-tractor owners increased from 9.3 per cent in 1920 to 29.6 per cent in 1925. The Southern State of Arkansas, which had only about 1400 tractor farmers in 1920, bought 3000 tractors in the 2 years ended July 1, 1925.—*Economic World.*

The Attendu Heavy-Oil Engine

By ANDRE C. ATTENDU[1]

ANNUAL MEETING PAPER *Illustrated with* PHOTOGRAPHS AND DRAWINGS

ABSTRACT

EFFICIENCY of the Diesel engine, on the first development of which in France the author worked, and the possibility of using the low-priced by-products of gasoline production, led to the designing and building of several experimental engines of small size and low weight to run on fuel oil and develop the power required for average automotive work. The theoretical and commercial requirements that established the basis on which these engines were designed and built are enumerated and each type of engine is described.

The first engine, which was built in 1921 and given its first test-runs in 1922, was a four-cylinder two-cycle engine operated on the air-injection straight-Diesel principle. Scavenging air was supplied by step cylinders and the injection air was supplied at a pressure of 1200 lb. per sq. in. by a small compressor built integral with the engine. The engine compression-pressure was 300 lb. and the fuel used was fuel oil of from 18 to 22 deg. Baumé gravity. This engine weighed 1100 lb. and was expected to develop 40 hp. at 1600 r.p.m., but in test-runs it ran at 1300 r.p.m., developed from 36 to 38 i.hp. and only 11 b.hp., and consumed nearly 2 lb. of fuel per b.hp. It was hard to start and oxidation of the fuel by the injection air caused the valves to leak. Nevertheless, it ran and was fairly flexible under load from 300 to 1300 r.p.m.

Tests of this engine made at McGill University gave results that led to the decision to build a second experimental engine, substituting solid-fuel injection for air injection to eliminate the air compressor, the intercoolers and the oxidizing effect of air on the fuel. This also was a four-cylinder engine, made of cast iron and having a compression pressure of 405 lb. The step cylinders for scavenging were retained and it operated on the same fuel as the first engine. In preliminary runs, the engine started on the first few revolutions, attained a speed of 1600 r.p.m. and developed 18 b.hp. Scavenging pressure was found to be too high and was reduced to 14 lb. Two transfer valves were substituted for the single valve and the rotary valves of the working cylinders were changed to poppet valves. To give better scavenging, the compressors, which originally discharged directly into the working cylinders, were connected to a common reservoir in the engine jacket and each working cylinder was scavenged with air from the reservoir. After these changes, the engine developed 46 b.hp. Changes in the fuel-pump and injector adjustments increased this to 56 b.hp. at 1400 r.p.m. Fuel consumption of the engine is at the rate of 0.76 lb. per b.hp. at from 1200 to 1400 r.p.m. and 0.87 lb. per b.hp. at 600 r.p.m. The engine idles down to 120 r.p.m. and starts readily from dead cold after three to five revolutions with a 6-volt starter.

Three engines of this type were built and a car fitted with one was operated about 3000 miles in the summer of 1924 without the slightest trouble. Two-thirds of this distance was run on a dirt track at an average speed of 27 m.p.h. and the fuel consumption was at the rate of 1 gal. per 19 miles. The car, fully loaded, weighed 5100 lb.

In August, 1924, a contract was secured from the Navy Department by the Eastern Engineering Co., Ltd., of Montreal, for the building of a two-cylinder experimental engine to determine whether a light-weight heavy-oil engine suitable for airship work would stand the high compression-pressures at high speed. This was built to operate on the same principle as the four-cylinder engine and designed to develop 100 hp. at 1500 r.p.m. or 125 hp. at 1750 r.p.m. and to have a weight of 3.8 lb. per b.hp. The only change in design is that the air compressor is on the side of the engine and the pistons of the working cylinders are of standard trunk design.

The aviation engine was delivered to the engine-testing laboratory at the League Island Navy Yard in February, 1925, and after several tests and improvements on adjustments, especially on the lubricating-oil system, showed a brake-horsepower output of 85 at 1620 r.p.m. In the builder's own laboratory, however, an output of 91 b.hp. at 1525 r.p.m. has been obtained and it is foreseen that, by making some alterations that are now in progress, an additional output of from 20 to 25 b.hp. can be obtained, thereby bringing the engine up to 110 or 116 b.hp. for a total weight of 417 lb., or 3.6 lb. per b.hp. Fuel consumption is now in the neighborhood of 0.6 lb. per b.hp-hr. and it is expected that this can be reduced to 0.5 lb. per b.hp-hr. The maximum recorded speed is 2210 r.p.m.

A complete detailed description of this engine is given in the paper and the author states that tests made with it definitely establish the facts that light metal can be used in the construction of heavy-oil high-speed engines and that this type is no more difficult to build than the present type of gasoline engine. From comparative data obtained by the running of the small four-cylinder engine and the experimental two-cylinder aviation engine, the design of engines of any size and with any number of cylinders can be calculated with close approximation of the results to be expected.

Possible applications of this type of engine include trucks, motorcoaches, rail-cars, airships, tractors, pleasure craft and tug with a low cost of power production that could not be dreamed of with the gasoline engine.

ATTRACTED by the great efficiency of the Diesel engine and the possibility of using the by-products of gasoline production, tremendous quantities of which were practically useless, I conceived the idea of building a small heavy-oil engine that would be light in weight, easy to construct, have fairly high speed and good flexibility, and that, if proved successful, would make possible the use of heavy fuel-oils in every possible field and in large quantities, with practical elimination of fire hazards and the production of power at the minimum cost.

Having worked on the first development of Dr. Diesel's engines in France and knowing their troubles and their requirements, I decided to build an engine of small size to develop the horsepower required for average automotive work. If this small size proved successful, it would be easy to build larger engines on the same principle.

THE REQUIREMENTS TO BE MET

The basis on which these experimental engines were worked-out embodied the following theoretical requirements:

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(1) For oil-burning engines, the first requirement is a definite and accurately measured quantity of oil for each stroke, this quantity varying with the engine speed or load

(2) In a high-speed engine, the time of injection of the fuel should be varied in accordance with the speed to avoid late burning

(3) In a variable-speed engine having a wide range of flexibility, the compression of air for combustion should remain practically constant regardless of engine speed, so that, when starting, the pressure built-up in the cylinder by the first few revolutions of the engine will raise the temperature sufficiently to burn readily the fuel the engine normally uses without the aid of an outside source of preheating or a firing device of any sort, or without using a lighter fuel for starting purposes. At high speed, the pressure should not exceed materially the pressure necessary to burn the fuel as soon as it is injected into the cylinders; higher pressures would require a heavier construction and experience has proved that unnecessarily high pressures are detrimental to good running of the engine and fuel economy and prolong general wear

(4) The controls, especially for motor-vehicle and aviation purposes, should be simple, effective and reliable and the response to the controls should be as instantaneous as that of the gasoline engine to its throttle or the timing of its spark

Commercial production of the high-speed heavy-oil engine demands

(5) The use of material already known and tested by the industry

(6) The use of machinery now employed in the production of the gasoline engine

(7) The use of standard fittings, bolts and other parts

(8) Above all, working tolerances which should be such that the engine could be built in quantity production with all parts interchangeable, as gasoline engines are built today

First Engine Gave Poor Results

The first engine was built in 1921 and the first runs were made in February, 1922, to see whether all the requirements mentioned could be met successfully. This engine, of the air-injection straight-Diesel principle, was a four-cylinder two-cycle engine with $3\frac{1}{2}$-in. bore and $5\frac{1}{2}$-in. stroke. The scavenging air was supplied by step cylinders and the injection air, at a pressure of 1200 lb. per sq. in., was furnished by a small two-stage compressor built integrally with the engine. The compression-ratio was 11 to 1, the compression pressure 300 lb. and the fuel used 18 to 22 deg. Baumé fuel oil. The engine was expected to develop 40 hp. at 1600 r.p.m. The fuel-pump was a two-stage pump, the first stage of which maintained a constant pressure of oil in a reservoir from which the four measuring pumps, one for each cylinder, were fed. The engine cylinders were of steel machined all over and screwed into a steel base. The weight of the engine was 1100 lb.

This engine ran at 1300 r.p.m. and developed only 11 b.hp., with a very poor fuel-consumption of nearly 2 lb. per b.hp-hr. The indicated horsepower was around 36 or 38 hp. The engine was hard to start because of its relatively low compression, the chilling effect of the injection air and the low grade of oil used. Nevertheless, it ran, was fairly flexible under load from 300 to 1300 r.p.m., and its peak was around 1200 r.p.m. It was noted that oxidization of the fuel by the injection air caused the fuel valves to leak.

Second Engine Has Solid-Fuel Injection

Results obtained with this first engine in tests made at McGill University led to the decision to build another experimental engine, this time with solid-fuel injection to eliminate the air compressor, intercoolers and the oxidizing effect of air on the fuel. This second type, which is shown in Fig. 1, was also a four-cylinder two-cycle $3\frac{1}{2}$ x $5\frac{1}{2}$-in. engine, but had a compression-ratio of 13 to 1. The material was cast iron and the cylinders were cast integrally with the crankcase. The step cylinders for scavenging were retained.

The second engine was completed in April, 1923, and started on the first few revolutions, using 18 to 22-deg. Baumé fuel. The speed attained was 1600 r.p.m. and on the first run 18 b.hp. was developed. The scavenging-air pressure of 34 lb. per sq. in. was found to be too high

Fig. 1—Second Type of Heavy-Oil Engine Built for Experimental Purposes

This Is a Solid-Fuel-Injection Engine of Four Cylinders and Operates on the Two-Cycle Principle, Using a Fuel of from 18 to 22 Deg. Baumé Gravity. The Cylinders and Crankcase Are of Iron, Cast Integrally. Step Cylinders Compress Air for Scavenging. This Engine Started on the First Few Revolutions and, After Some Changes in Valves and Scavenging and Fuel Adjustments, Attained a Speed of 1800 R.P.M. and Developed 56 B.Hp. at 1400 R.P.M., with Fuel Consumption at the Rate of 0.76 Lb. per B.Hp-Hr. One of Three Engines of This Type Was Run in a Car for 3000 Miles in the Summer of 1924. Total Weight of the Car Was 5100 Lb. and, at an Average Speed of 27 M.P.H. on a Dirt Track, the Fuel Consumption Was 1 Gal. per 19 Miles

and the scavenging was imperfect. At the time, only one transfer valve was used and the intake-valves of the scavenging cylinders as well as the exhaust-valves of the working cylinders were of rotary type. After the first tests, the rotary valves were changed to poppet valves, two for each cylinder, and two transfer valves were fitted to each working cylinder. By these changes the brake-horsepower was brought up to 36. Other changes were made on the scavenging compressors, which originally discharged directly into the working cylinders through cross ports. The compressors were connected to a common reservoir fitted in the jacket of the engine, and each working cylinder was scavenged with air taken from that reservoir at a pressure of 14 lb. per sq. in. Then the engine developed 46 b.hp. Finally, by trying different adjustments on the fuel pump and injectors, the brake-horsepower was increased to 56 at 1400 r.p.m. The maximum speed of the engine under load is 1800 r.p.m., at which speed the brake-horsepower falls to 38, the peak being around 1400 to 1425 r.p.m. Fuel consumption is at the rate of 0.76 lb. per b.hp. for speeds ranging from 1200 to 1400, and 0.87 lb. per b.hp. at 600 r.p.m. This engine, in normal condition, idles down to 120 r.p.m. Fitted with a 6-volt starter, it starts readily from dead cold after three to five revolutions on 18 to 22-deg. Baumé fuel.

Three engines of this type were built, one of which was put in a car with which tests were run during the entire summer of 1924, covering approximately 3000 miles, without the slightest trouble. Two thousand of the 3000 miles was run on a dirt track at an average speed of 27 m.p.h. and a fuel consumption of 19 miles per gal. of fuel oil. The car weighed, fully loaded, 5100 lb.

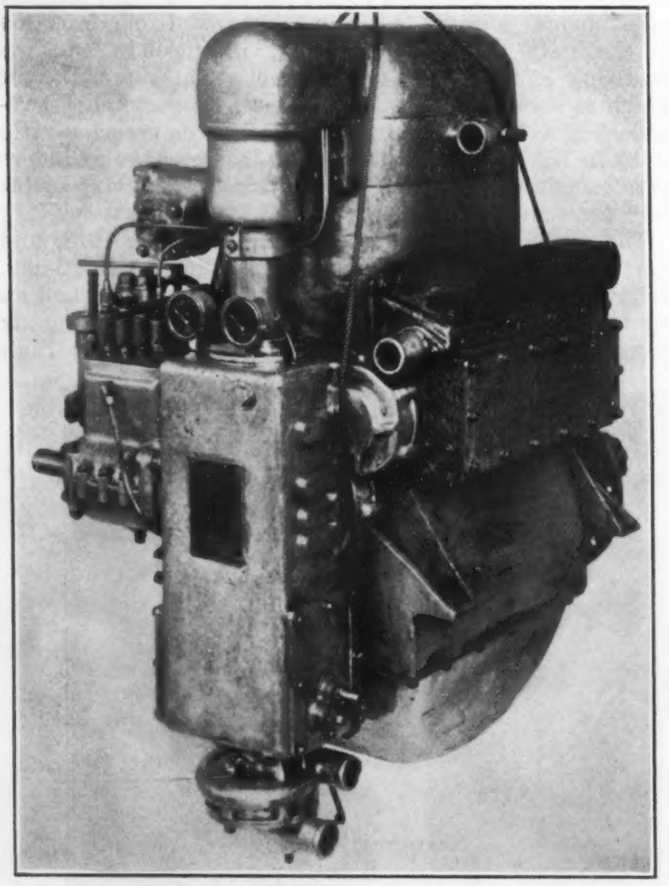

Fig. 2—Two-Cycle Solid-Injection Aviation Engine Built for the Navy Department

This Is of Aluminum and Was Designed and Built To Determine Whether or Not a Light Engine Suitable for Aviation Work Would Stand the High Compression-Pressures at High Speed. It Has a Total Weight of 417 Lb. and Developed 85 B.Hp. at 1620 R.P.M. at the Engine-Testing Laboratory at the League Island Navy Yard and 91 B.Hp. at 1525 R.P.M. in the Builder's Own Laboratory. Fuel Consumption Is About 0.6 Lb. per B.Hp-Hr. The Maximum Recorded Speed Is 2210 R.P.M.

Aviation Engine Built for the Navy

One of these engines was taken to the City of Washington in October, 1923, to demonstrate the principle to the Patent Office. During these tests, in August, 1924, the Eastern Engineering Co., Ltd., obtained a contract from the Navy Department, on the recommendation of Lieut.-Com. E. E. Wilson, of the Bureau of Aeronautics, for a two-cylinder experimental engine, to determine whether an engine of light weight would stand high pressures at high speed, that is, whether the heavy-oil engine was suitable for airship work.

This two-cylinder engine, embodying the same principle as the small four-cylinder type, has a bore of 5½ in. and a stroke of 6½ in. and was designed to develop 100 b.hp. at 1500 r.p.m. or 125 hp. at 1750 r.p.m., and to have a weight of 3.8 lb. per b.hp. It is shown in Fig. 2. The only change in design from the four-cylinder type is that the air compressor is on the side of the engine and the pistons of the working cylinders are of the standard trunk design. It was a condition of the contract that all experiments on the engine were to be made at the engine-testing laboratory of the League Island Navy Yard, Philadelphia.

The engine was delivered in February, 1925, and ran fairly well up to 1800 r.p.m., but lubrication and minor mechanical troubles developed in the valve adjustment, couplings and elsewhere, which delayed the official tests until the end of November, 1925, when the first test was passed successfully and the title to the engine vested in the United States Government.

When first delivered, the engine developed 61 b.hp. at 1350 r.p.m. With improvements on the adjustment and especially on the lubricating-oil system, the brake-horsepower increased to 76 at 1360 r.p.m., 82 at 1610 r.p.m. and 85 at 1620 r.p.m. The best power output, 91 b.hp. at 1525 r.p.m., was obtained in our own laboratory. We can foresee, however, that by making some other alterations that are now in course of execution an additional output of from 20 to 25 b.hp. can be obtained, which will bring the engine up to between 110 and 116 b.hp. for a total weight of 417 lb., or 3.6 lb. per b.hp. The fuel consumption is now in the neighborhood of 0.6 lb. per b.hp-hr., and the expectation is to reduce it to 0.5 lb. The maximum speed recorded with this engine is 2210 r.p.m.

Construction and Operation in General

This aviation engine, which is the most recent and advanced engine that I have built, is of the high-compression self-ignition type. It operates on the two-stroke cycle, using solid, that is, airless, injection and can be started from cold on its normal fuel, which is 0.93-specific-gravity fuel-oil. The engine is extremely flexible; it is capable of maintaining a high torque throughout a speed range of from 400 to 1600 r.p.m. This flexibility is obtained by refinement in the regulation of the fuel pump and by a patented system of compression-pressure control.

This engine has two cylinders, 5½ x 6½ in., and a rated output of 100 b.hp. at 1500 r.p.m. Port scavenging and uni-directional flow of air and gases are obtained by placing the inlet-valves in the head. A large-diameter short-stroke air-pump is mounted at the side of the

engine, with its axis nearly horizontal. It is double-acting and is driven at crankshaft speed by a lay-shaft that also operates the exhaust-valves. These valves, two per cylinder, are set in a pocket close to the exhaust ports and their time of closing is governed by an automatic control. The valves are always open when the piston uncovers the exhaust ports, but are closed at a variable point before the ports are covered again. By variation in this point of closing, the effective length of the compression stroke is altered. Thus, in starting and at the lower speeds, a greater volume of air is retained in the cylinder to compensate for the slow compression and consequently greater losses of heat and pressure. Thus the final compression-pressure may be held at a

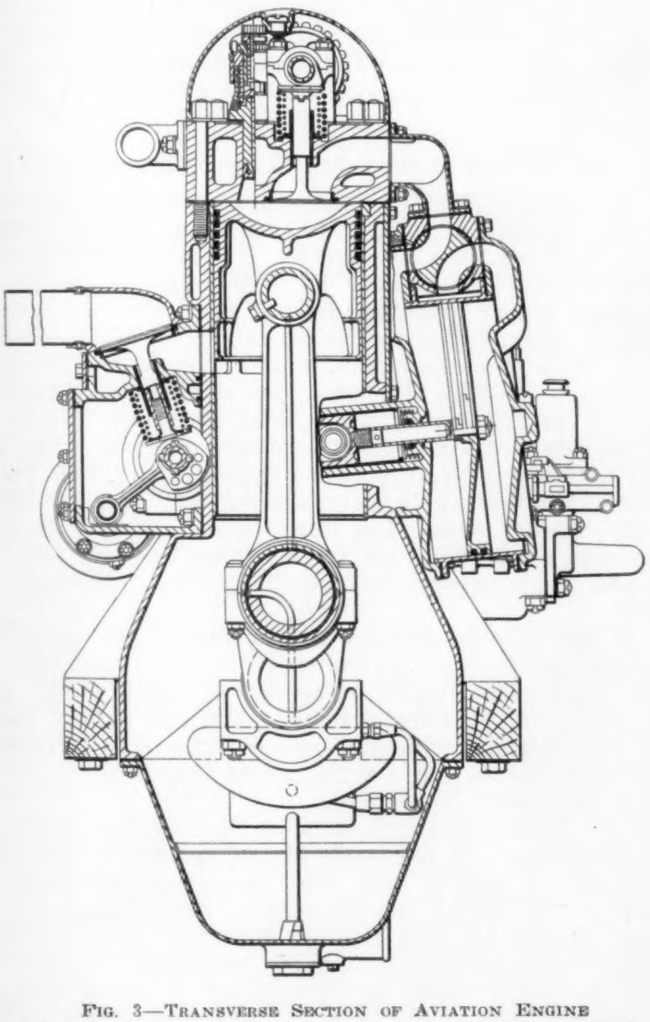

FIG. 3—TRANSVERSE SECTION OF AVIATION ENGINE
A Large-Diameter Short-Stroke Air Compressor for Scavenging Is Located on the Right Side and Is Driven from a Lay-Shaft That Operates the Exhaust-Valves on the Left Side. A Single Rotary Valve above the Pump Controls the Air on Both Sides of the Pump Piston. The Air-Inlet Valves, of Poppet Type, Are Near the Center Line of the Cylinder-Head and Are Operated by an Overhead Camshaft. Two Exhaust-Valves per Cylinder Are Located Close to the Exhaust Ports on the Left Side in a Pocket. The Time of Closing Can Be Varied, Thereby Altering the Compression, a Greater Quantity of Air Being Retained in the Cylinders When Starting and at Low Engine-Speed. The Engine Is of the Self-Ignition Type

sensibly uniform value. This is an essential feature of the Attendu engine and is shown in section in Fig. 3.

ELEMENTS OF THE FUEL SYSTEM

The fuel-injection system comprises three main elements: (*a*) a primary, or low-pressure, pump; (*b*) a high-pressure pump that meters and injects the fuel and (*c*) a spray nozzle or injection valve.

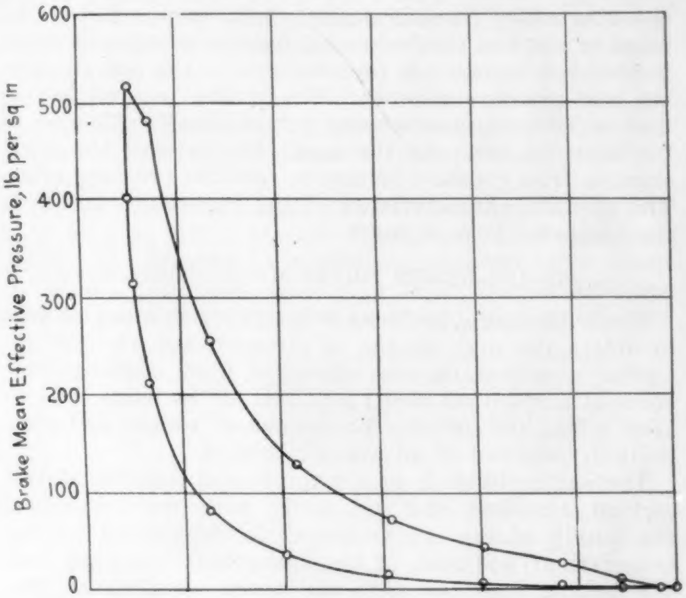

FIG. 4—INDICATOR DIAGRAM OF AVIATION ENGINE AT 600 R.P.M.
Timing of the Fuel Injection Is Arranged So That Sensibly Constant-Volume Combustion Is Obtained at the Lower Speeds

Both the primary and injection pumps are of the single-acting plunger type and are operated from a common shaft, on which are two primary plungers driven by eccentrics. These supply two injection plungers, one per cylinder, which are cam-operated. The low-pressure stage is required to draw fuel oil from the tank and to ensure the rapid and complete filling of the high-pressure cylinder. Variation in the power output of the engine is obtained by controlling the quantity of fuel injected at each stroke and this is accomplished by lifting or lowering the high-pressure plungers in relation to the cams. This action has the effect of altering the point at which injection commences, but this is automatically compensated for by the timing mechanism of the pump. In addition, a wide range of timing control is available.

The injector consists essentially of a nozzle that is controlled by a spring-loaded needle-valve. This valve

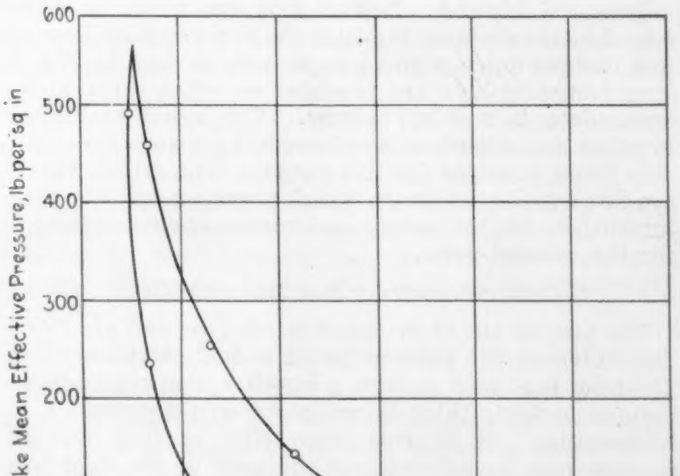

FIG. 5—INDICATOR DIAGRAM OF AVIATION ENGINE AT 1000 R.P.M.
As the Engine Speed Increases the Cycle Changes Automatically from the Constant-Volume to the Constant-Pressure

is set to retain its seat against the pressure due to the primary stage of the fuel-pump, but opens promptly upon the marked increase in pressure due to the operation of the high-pressure plunger. The timing is arranged so that sensibly constant-volume combustion is obtained at the lower speeds. As the speed is increased the cycle changes from constant-volume to constant-pressure cycle. The pressure characteristics of the engine are shown in the diagrams, Figs. 4 and 5.

Engine Design Solves Major Problem

The outstanding problem in designing this engine was to obtain the high degree of strength and rigidity required to withstand the somewhat high working-pressures at a speed of 1600 r.p.m. and at the same time to keep within the extreme limitations of weight and compactness required of an aircraft engine.

The engine block is of aluminum and consists of two vertical cylinders cast integrally with the crankcase. The length of the engine proper is determined by the arrangement and area of the crankshaft bearings, and this length, together with the space occupied by the propeller-hub and valve-gears, fixes the over-all length of the engine. At the front end, the crankcase is brought forward in a nose, as shown in Fig. 6, to provide clearance for the radiator when the engine is installed in an airplane. This nose houses the thrust bearing and permits the use of a very substantial front main-bearing. Each bearing is supported by a simple system of two longitudinal and two transverse ribs that carry the load directly to the cylinder-barrels and supporting lugs and form a very rigid assembly. At the rear end, these ribs are arranged to form a mounting for the valve-gear housing, which is a separate casting.

Height of the engine is determined by the stroke, the minimum length of the connecting-rod and the length of piston above the piston-pin. The thickness of the head and the space occupied by the overhead camshaft have been held to the minimum. The walls of the crankcase have been carried down to 3 in. below the level of the crankshaft to provide extra stiffness. The cylinders are encased in a water-jacket from the top to below the exhaust-ports.

Width of the engine is fixed by the path of the connecting-rod big-end. Beyond this the width is determined by the distance to which the exhaust-valve housing and fuel-pump are allowed to project, as seen in Fig. 3. Two mounting-lugs are provided on either side to accommodate 2 x 3-in. bearers. The usual crankcase-breather is omitted, a cored passage between the cylinders being arranged for this purpose. The cylinder bores are fitted with steel liners, which provide a suitable bearing surface for the pistons and ensure adequate strength for the exhaust-ports.

Construction of Pistons and Rods

The pistons are of the usual trunk type and are fairly long to cover the exhaust ports at bottom dead-center. The head is cupped to form a compact combustion-chamber and is fairly thick to ensure an even distribution of temperature. It is free from ribs so that heating stresses may be reduced and the path of the heat-flow may be kept as far as possible from the piston-pin bosses The clearance is 0.020 in. at the top and 0.005 in. at the skirt, which is slightly in excess of the usual practice with cast-iron pistons. The piston is fitted with five plain rings 3/16 in. wide. The cylinder is lined with mild-steel tubing and is not ground, being lapped by motoring-over with the rings in place.

The piston-pin is of mild-steel tubing, case-hardened on the outer surface, and is arranged to afford the maximum area and stiffness in the bearing. A steel tube is used to convey oil from a tube on the connecting-rod to the bearings on either side. From these it flows to the cylinder-walls through two vertical holes drilled in the piston.

The connecting-rod is cut from chrome-nickel steel and is heat-treated to afford the maximum strength and toughness. It is of the usual H-section type and is made slightly larger at the lower end to provide a good distribution of the load over the big-end bearing. The latter is fitted with a babbitt-lined bronze bushing, pinned in place. Oil is conveyed to this bearing through the crankshaft and is carried to the piston-pin through a light steel-tube. The big-end cap is held in place by four bolts of comparatively small size, since they are loaded only in the event of a failure of an inlet-valve, which would destroy the cushioning effect of the compression.

Two-Throw Crankshaft Is Counterweighted

The crankshaft is of chrome-nickel steel and has two cranks disposed at 180 deg. to each other. The journals are of $3\frac{1}{4}$-in. outside diameter and are drilled-out to lighten them. Oil is carried to the crank-pin bearings through copper tubes, swedged in place. At the front end of the crankshaft is the mounting for the propeller-hub. This is of the tapered type and is fitted with one large key. Behind the hub is the seating and jam-nut for the thrust bearing, which is of the radial type and is capable of taking thrust in either direction without any tendency to wedging of the balls at high speed. The front main-bearing is made exceptionally long to deal with external loads. The intermediate and rear main-bearings are designed for the maximum gas-load, which is taken at a pressure of 1000 lb. per sq. in. of piston area.

As this is a two-cylinder engine, two bronze counterweights are mounted on the shaft outside of and opposite to the crank throws. They are of sufficient size to absorb all the centrifugal moment and also part of the primary moment, without, however, introducing serious horizontal forces that are difficult to absorb in the airplane structure.

The propeller-hub chosen is of the proposed S.A.E. Standard type. It is capable of easy production and is arranged to give a very close mounting adjustment without the use of delicate parts. The flywheel hub, which is used for testing, is the same part as the inner flange of the propeller-hub, partly machined. For testing, the outer flange is replaced by a dynamometer coupling.

The main-bearing bushings are of bronze-backed babbitt. The caps are cut from chrome-vanadium steel and are designed as I-beams, with reinforcement at the edge of the upper flange, and are exceptionally stiff. The main-bearing studs are of chrome-nickel steel.

The front end, or nose, of the engine body is closed with a small cover threaded over the crankshaft. This cover is ribbed to provide a rigid shoulder for the thrust bearing and is fitted with a felt ring to retain oil.

The oil-pan is of the usual type and is a thin aluminum-casting. It is fitted with an oil-screen. Since the lubricating system is of the dry-sump type, the pan will normally contain very little oil, as the oil is removed by a scavenging pump as fast as it accumulates to prevent flooding of the cylinders should the airplane be dived or inverted.

Valve-Gears Housed in Removable Units

The gearing that drives the camshafts and the auxiliaries is mounted in an aluminum housing at the rear of the engine body. This housing, with its backplate, forms a self-contained unit that can be dismounted from the engine without disturbing any other part. The upper half, which carries the gears and fuel-pump, is reinforced with a tubular strut, while the lower half is comparatively light. The gears are of spur and bevel types and are all mounted on ball bearings. The bearings are disposed on either side of the gear, one in the housing and one in the backplate. In each case the bearing that carries the thrust of a bevel-gear is rather larger than the other of the pair.

At the top of the housing is a circular plate that carries the end of a vertical shaft which drives the inlet camshaft. This shaft is enclosed in a light steel-tube that serves to carry the return oil to the sump. Both shaft and tube can be slid up out of engagement when it is necessary to remove the housing.

At the left side of the housing is the fuel-pump, and at the right side is the coupling that drives the exhaust camshaft and air-pump. This coupling gives a wide range of timing and obviates the necessity of exact alignment. At the same time, it facilitates the disassembling of the exhaust-valve housing. Provision has been made to mount a governor for the exhaust-valve control or the water-pump on this side. The lower part of the housing contains the lubricating-oil pump and filter, and the water-pump is mounted below the housing.

All the auxiliaries are accessible from the sides or below the engine, and the rear of the housing has been kept clear of openings and extensions so that the engine can be mounted close to the fireproof bulkhead and tanks in the airplane.

The valve-gear upper-housing is separate from the unit just described and is bolted to the rear of the cylinder-head. It provides a mounting for the gears that drive the inlet camshaft and the valves of the air-pump. The vertical driving-shaft engages with the lower end of a short spindle mounted in this housing. Toward the lower end of this spindle is a spiral gear that drives a cross-shaft which extends out to the left side of the engine, where it drives the air-pump valve through a second pair of spiral gears and a short horizontal shaft running forward. At the rear end of the latter is an S.A.E. Standard tachometer-coupling. These spiral gears are of fine pitch, and all shafts are mounted on ball bearings.

At the upper end of the spindle is mounted a pinion that meshes with a larger bevel-gear. This gear is aligned with the inlet camshaft, which it drives through a short spindle and modified Oldham coupling. This arrangement permits the removal of the vertical spindle or the inlet-valve camshaft without disturbing any other part and is of considerable advantage in connection with directly-operated valves. Provision is made to set the timing of the air-pump valve and inlet-valve camshaft within close limits.

Cylinder-Head of Cast Aluminum

The cylinder-head is of cast aluminum and is held to the engine body by 20 studs of chrome-nickel steel. It is of comparatively small over-all depth but is well reinforced by a system of internal ribs, which, together with the walls of the inlet passages, form a somewhat complex I-beam, as will be noted in Figs. 3 and 6. The top and bottom faces of the head, which form the flanges, are of increased thickness out to the stud circle. The inlet passages are as smooth and regular as possible to interfere as little as possible with the high velocities attained by the scavenging air at normal speed. The cooling-water passage is arranged so that all parts of the head that are not actually occupied by the valves or injectors are in contact with the water. This construction, in conjunction with the use of aluminum, appears effectively to prevent local overheating and consequent distortion of the head.

The cylinder-head studs are screwed into the engine body with an S.A.E. thread. The prevalent objection to the use of a fine thread in aluminum appears to be based on cutting difficulties, since a series of tensile tests has demonstrated that this design is entirely sound. By this arrangement a very efficient use of the space is obtained and the outside diameter of the cylinder is held to the minimum.

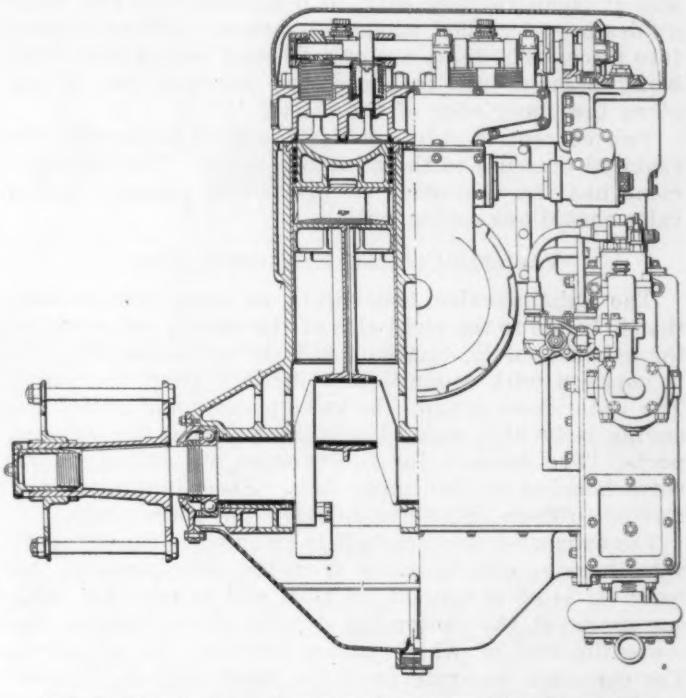

Fig. 6—Elevation of Aviation Engine on Fuel-Pump Side
The Crankcase Is Brought Forward to a Nose To Provide Clearance for a Front Radiator and To House a Long Main Crankshaft-Bearing. The Cylinders Are Steel Lined and the Two-Throw Crankshaft Is Counterweighted. The Fuel-Pump and Valve-Gear Housings Are Mounted at the Rear of the Engine and Are Separate Units That Are Removable without Disturbing Other Parts. A Cast-Aluminum Cylinder-Head, of Low Height and Reinforced by Internal Ribs, Is Used

The cylinder-head cover is a thin aluminum-casting that closely encloses the inlet camshaft, valves and injectors. Its functions are to retain the lubricating oil, exclude dust when running-up the engine on the ground and improve the streamlining of the installation. It is retained by four nuts that are fixed in the cover and engage with the studs of the inlet-valve-camshaft brackets.

Details of Inlet-Valve Camshaft and Valves

The inlet-valve camshaft and inlet-valves are mounted in the cylinder-head and are located ½ in. off the center-line. This arrangement permits using the largest possible valves with the minimum displacement of the injector. The shaft carries four integral cams arranged in pairs disposed at 180 deg. The cam faces are of tangential form, which, with flat followers, gives somewhat severe accelerations, a condition that appeared at first to be unavoidable, in view of the volume of air to be dealt with and the short time available for its pas-

sage. Oil is supplied under pressure to the rear bearing of the camshaft and flows through the hollow shaft to all other bearings and the cam faces.

The inlet-valves are of the mushroom type. They are made of chrome-nickel steel and are provided with shoes of the same material, which are screwed into the valve-stem to take the thrust of the cam and are retained by a locking-plate assembled between the shoe and the valve-spring. The plate is held by slots cut in the stem and is provided with a series of shallow cups any one of which can be engaged with a ball let into the shoe and which is retained in position by the pressure of the inner spring. This arrangement is compact and simple and is comparatively easy to manufacture. The valve guides are of chilled manganese-bronze and are pressed into place. The seats are of mild-steel tubing and, after being pressed into the head, are swedged into a slot along the upper edge of the skirt.

Two concentric valve-springs are used to develop the required pressure in the minimum space. This arrangement has the advantage of preventing damage to the valve should one spring fail.

Variable-Closing Exhaust-Valves

The exhaust-valve housing is an aluminum casting that is bolted to the right side of the engine and contains the exhaust-valves, camshaft and shifter mechanism. It is supplied with cooling-water directly from the pump. The water flows around the valve pockets and enters the engine body at a point immediately below the exhaust ports. The headers for the exhaust are bolted to the valve housing on the upper face. Sheet-iron pipes are riveted to these and serve to carry the gases away.

The exhaust-valve camshaft is mounted in the exhaust-valve housing and is driven from the valve-gears at the rear. It is of chrome-nickel steel and is provided with one crank at the center for driving the air-pump, the connecting-rod of which passes between the cylinders. The cams are separate from the shaft and are rotated by sleeves that are also separate from the shaft but are driven therefrom by adjustable timing-flanges. This latter drive is normally locked in place, but the sleeves are cut with spiral splines on the outer surface and the angular relation of the cams can be altered while the engine is running by sliding them along the sleeves by shifter-forks. The cams are in pairs, as there are two valves per cylinder, and are formed with a slow-lifting contour and tangential closing-face.

The point of closing of the valves is determined by the longitudinal position of the shifter-forks, which are mounted on a parallel shaft. This shaft is carried in a pair of steel bushings at the ends and the forward bushing is arranged to form a hydraulic cylinder. It is supplied with oil under pressure from a separate unit of the lubricating-pump which causes a piston mounted on the shifter-fork shaft to move out against a spring load. A series of small holes is drilled along the cylinder-barrel and the outward movement continues until a sufficient number of these holes has been uncovered to permit the oil to escape. The rate of oil input, and hence the position of the exhaust-valve cams, is thus determined by the speed of the engine and lubricating-oil pump.

The exhaust-valves are very similar to the inlet-valves but are larger and have a higher lift to deal with the greatly increased volume of the gases at the exhaust temperature. The valve shoes and springs are interchangeable throughout. The seats of chilled manganese-bronze, now changed to steel, are pressed into place and clamped by the exhaust headers, which are bolted on top.

The camshaft is mounted on four plain bearings and is supplied with oil under pressure. The shaft can be removed from the housing without dismounting and the timing may be altered with the shaft in place.

Slow-Speed Short-Cylinder Air-Pump

The air-pump is mounted on the left side of the engine, as shown in section in Fig. 3, and is driven from the shaft that operates the exhaust-valves. This arrangement has the advantage of extreme compactness, of permitting the use of a short and direct inlet-manifold and of affording complete accessibility to other parts. The bore is 9¾ in. and the stroke 3 in., which gives a very low piston-speed and shortens the cylinder to such an extent that it is possible to employ a single rotary valve to control the air at both sides of the piston, with very little increase in the clearance volume.

The cylinder-barrel is of steel and the heads of aluminum with cored air-passages. The piston is of the conical type and is made of forged and heat-treated aluminum. It is fitted with two cast-iron rings. The piston-rod is of steel, with an aluminum cross-head, and works through a spring-loaded packing-gland. The connecting-rod is of the same type as those of the working cylinders but is much smaller. It is fitted with a babbitt-lined big-end and is lubricated under pressure from the exhaust-valve camshaft.

The valve consists of an aluminum cylinder cored with two curved passages for the air. It is rotated in a steel-lined housing at half crankshaft-speed and is driven from the upper valve-gear assembly through a short horizontal shaft. It is lubricated under pressure and the surplus oil serves to lubricate the piston. A short manifold carries the air to the valves in the cylinder-head.

Compound Fuel-Pump with Variable Period and Timing Control

The fuel-pump assembly, shown in Fig. 7, is mounted at the rear of the engine on the left side of the valve-gear housing. The body is of aluminum, the cylinder-block is of steel and the control mechanism is in a bronze casting. The pump is driven from the gear that serves as idler for the exhaust-valve camshaft, through a modified form of epicyclic transmission that functions as an advance mechanism. The driving member is an internal-toothed ring-gear that meshes with a set of three planetary pinions, the spindles of which form the driven member. A central gear revolves with the assembly, locking it as a single unit, but is capable of further rotation for about one-half revolution. This action is accomplished by the longitudinal movement of a central spindle upon which the central gear is mounted and which is cut with both straight and spiral splines. The movement is carried out by a rack-and-pinion device and causes alteration in the timing of the entire pump.

The pump shaft is provided with two eccentrics that drive the low-pressure plungers and two cams that actuate the high-pressure plungers. The low-pressure cylinders are supplied with oil from the fuel tank through two inlet-valves and force it to the high-pressure cylinders through two transfer valves, all of the poppet type. From this point the oil is conveyed directly to the injectors without the interposition of any chambers or valves.

The control mechanism of the pump can be divided into that part which governs the period and that which governs the timing of the injection. The former function is accomplished by lifting the plungers from the cams so that they engage only the peak of the cams

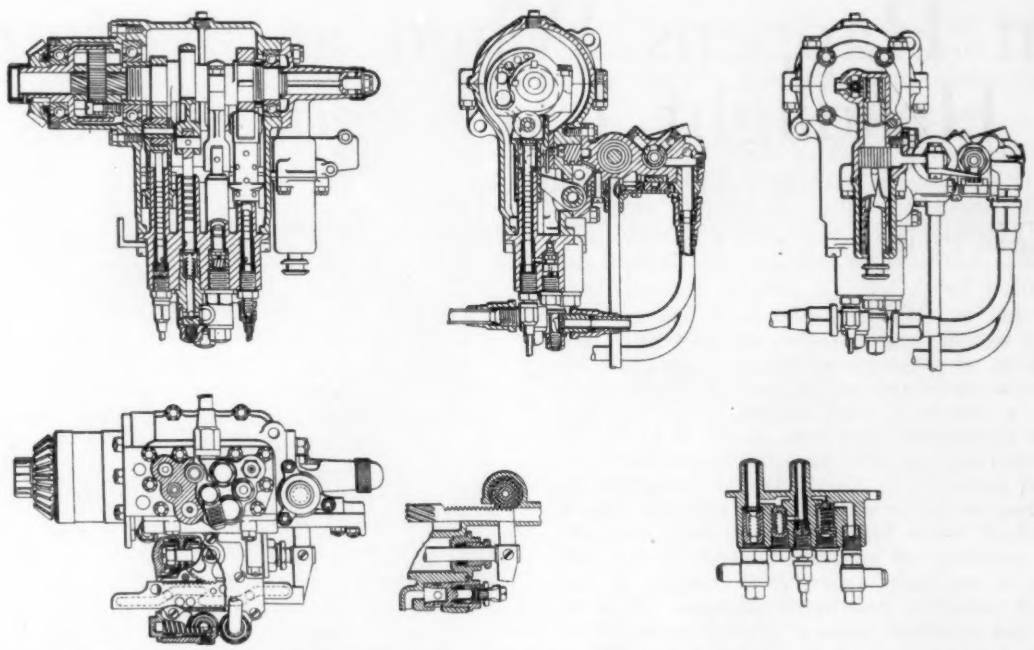

FIG. 7—FUEL-PUMP ASSEMBLY IN TRANSVERSE AND LONGITUDINAL SECTIONS AND PLAN VIEW
This Has Both Low-Pressure and High-Pressure Cylinders and Fuel Is Conveyed Directly from the Latter to the Injectors without the Interposition of Any Chambers or Valves. Period of the Pump Is Varied by Raising the Plungers from the Cams. Alteration in the Timing of Injection Is Accomplished by a Rack-and-Pinion Device Acting on a Spirally Splined Shaft To Rotate the Central Gear About One-Half Revolution

under light-load conditions and are totally disengaged to stop. This arrangement, while very simple, has the obvious disadvantage of retarding the point of injection progressively as the plungers are withdrawn. Accordingly, an automatic correction is applied by inter-connection of the control mechanism with the timing-gears previously described, so that the point of injection is maintained at a constant relation regardless of the lift. In addition, a wide range of timing control is available and can be set by an independent lever. The rapid shifting of the control mechanism requires more effort than can conveniently be applied by hand and this movement is therefore carried out by a servo-motor.

Upon moving the hand lever, a valve is displaced and surplus oil from the low-pressure stage of the pump is admitted to either end of a double-acting cylinder, thus causing a piston to move in or out. This motion is transmitted through a rack and pinion to the plunger lifter-forks and also to the advance gear. The movement having reproduced the original displacement of the hand lever, the servo-motor valve is automatically returned to the closed position.

The injectors are essentially the high-pressure discharge valves of the fuel-pump. They are removed from the pump and placed at the cylinder-head to obtain better control of the fuel spray, more especially at the beginning and end of the injection. It is important that a sharp start and cut-off be obtained, since any dribble tends to cause delayed combustion and inefficiency. The injector is fitted with a needle-valve that controls a small port opening directly into the cylinder. Upon movement of the high-pressure plunger of the fuel-pump, the oil forces the valve off its seat against the pressure of the spring. At the end of its stroke, the needle comes into contact with a spring-loaded buffer that permits a slight further movement under increased pressure. This tends to prevent surging of the valve and provides a slightly larger opening for heavy loads.

Fuel oil is carried to the injector through small-diameter steel tubing and special fittings that are capable of retaining it under pressure, which attains as much as 12,000 lb. per sq. in. at high speeds.

THREE-IN-ONE LUBRICATING-OIL PUMP

The lubricating-oil pump is mounted at the right of the valve-gear housing. It consists of three separate units contained in a common casing and is driven from the main gear on the crankshaft at 1.6 times the crankshaft speed.

The first unit is a pressure pump that supplies the main bearings and, through a reducing valve, the camshafts and air-pump. Its oil supply is from a filler mounted on the left side of the housing. Behind this is a scavenging pump that removes the oil from the sump to an external tank. At the rear is a small pump that supplies oil from the filter to the hydraulic exhaust-valve control-gear. The pressure lines are fitted with spring-loaded ball relief-valves.

In the present design the water-pump is at the bottom of the valve-gear housing. It is of the centrifugal type and has a 4-in. rotor. It is rotated at crankshaft speed through a separate set of gears and is fitted with spring-loaded packing-glands. Its low position renders it suitable for use with either side or nose radiators and makes it accessible from below the fuselage.

Tests made with this engine definitely established the fact that light metal can be used in the construction of heavy-oil high-speed engines, and also that this type of engine is no more difficult to build than the present gasoline engine. Comparative data collected from the running of the small four-cylinder engine and the experimental two-cylinder aviation engine, allow us to calculate the design of engines of any size and any number of cylinders with a close approximation of the results to be expected from such engines.

The possible applications of the light high-speed heavy-oil engine are manifold. They include pleasure craft, tugs, tractors, motorcoaches, rail-cars, motor trucks, and airships, and, in the not very remote future, passenger automobiles.

What Happens When an Automobile Headlight Is Out of Focus

By L. C. Porter[1] and G. F. Prideaux[2]

Annual Meeting Paper *Illustrated with* Charts and Photographs

ABSTRACT

SINCE the layman and not the engineer buys and drives most of the automobiles produced and because the literature on automobile headlighting presents too technical a picture of what happens when the light source of an automobile head-lamp is out of focus, the authors planned and executed an extensive study of the subject in an endeavor to clarify the technicalities by presenting them in the forms of photographs and simple charts, the chief object being to obtain data that emphasize the necessity of accurate control of the size and location of the light source with respect to the focal point of parabolic headlight-reflectors. A great difference in the resultant beam of light is produced by a very small displacement of the light source, either through poorly constructed lamps or due to lack of proper adjustment, and the tests made evaluate how small these displacements and how great these differences are.

After considering the difficulties of locating the light source or filament of the 21-cp. headlight-bulb at the exact focal point of the reflector and of taking account of the practice of certain manufacturers who measure tolerances in sixty-fourths of an inch and of trouble due to wabbly sockets, distorted reflectors and the like, the authors constructed a device that enabled the lamp socket to be moved in any direction by micrometer screws having 32 threads per in., thus causing a one-half revolution of the screws to move the light source exactly 1/64 in., backlash being compensated for by springs. A test reflector made as perfectly as possible was used in connection with the device. Variations due to filament size, shape or relative position in the bulb, were eliminated so far as possible by selecting lamps exactly correct as to light-center length, axial alignment and bulb image, and the same lamp was used for all the light-center length and axial-alignment tests, these being made by moving the one lamp with the aforesaid accurate focusing-device. Three types of lamp were chosen to give beams of wide, medium and narrow spread, and, with this equipment, the authors set out to ascertain the effects of various specified changes in equipment arrangement and to record them by photographs, as well as by photometric and linear measurements.

In making the measurements, the test reflector with the universal focusing-device was mounted on a rotatable table, graduated in degrees, located 25 ft. from a screen having the Illuminating Engineering Society's headlight-specification test-points plotted upon it. Photometric readings were taken with a Macbeth illuminometer. The headlight-lamps were operated at exactly 21 mean spherical cp. A single reflector was used. The tests brought out clearly the need for accurately made lamps and equipment and for accurate focusing if the headlight situation is ever to be brought under control.

ANYONE who has studied automobile lighting, and many who have not, know in a general way what happens when the light source is out of focus. Search of the literature on the subject, however, fails to reveal information that can be clearly understood by the layman and, after all, it is the layman and not the engineer who buys and drives most of the cars. Plenty of information is available in technical or semi-technical journals describing the lumen output of a headlight having a paraboloidal reflecting-surface. The brilliancy of the road surface in milli-lamberts can be calculated and the beam candlepower can be determined 7 deg. to the left or 4 deg., above the lamp axis and the like. Photometric distribution-curves are available, headlight laws have been passed and ideal beams have been described, but what have we in actual operation on our roads and what do the results *look* like? In an endeavor to reduce some of these technical data to plain English and to tell the story by photographs and simple charts, we planned and executed a rather extensive study that is described in the following condensed form.

The chief object of this study was to secure data that would emphasize the necessity of accurate control of the size and location of the light source with respect to the focal point of parabolic headlight-reflectors. Few automotive engineers realize how small a displacement of the light source, either through poorly constructed lamps or lack of proper adjustment, will make a very great difference in the resultant beam. Just how small and how great these differences are is clearly shown by the accompanying results of tests.

Testing Equipment

Certain special types of reflector and of lens are not as sensitive to focal adjustment as is the true paraboloid. Obviously, these data do not hold for such equipment. We had heard and read much about the difficulties of locating the light source of filament of the 21-cp. headlight-bulb at the exact focal point of the reflector. We also had learned of certain manufacturing tolerances measured in sixty-fourths of an inch, which the lamp manufacturers claimed were necessary in making the bulbs. We had heard also of wabbly sockets, distorted reflectors and the like; so, to eliminate all these troubles, we had a focusing-device such as that shown in Fig. 1 made-up in our machine-shop, which enabled us to move the socket in any direction by micrometer screws having 32 threads per in. With this device, a one-half revolution of the screws moves the light source exactly 1/64 in., no more and no less, any backlash being taken-up by springs. A test reflector, made as true and as perfect as the best reflector-manufacturer in the Country could construct it, was used with the focusing device.

To eliminate any variations due to filament size, shape or relative position in the bulb, we selected lamps that were exactly correct as to light-center length, axial alignment and bulb image, and the same lamp was used for all the light-center-length and axial-alignment tests; these being made by moving the one lamp with our accurate focusing-device. Three types of lens were chosen to give beams of wide, of medium and of narrow spread. With this equipment we set out to ascertain the following ef-

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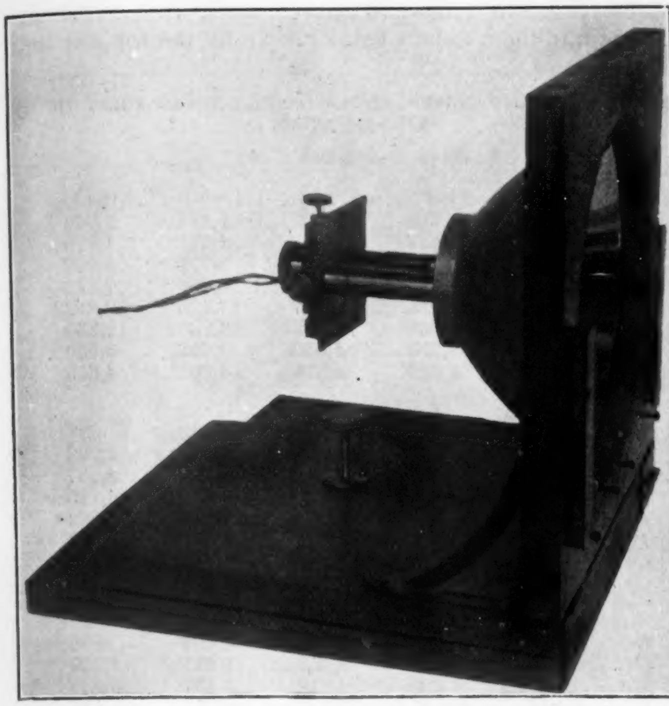

FIG. 1—MICROMETER FOCUSING-DEVICE AND TESTING REFLECTOR
The Device Permits Movement of the Socket in Any Direction by Micrometer Screws Having 32 Threads Per In. A One-Half Revolution of the Screws Moves the Light Source Exactly 1/64 In., Any Backlash Being Taken-Up by Springs

fects and to record them by photographs, as well as by photometric and linear measurements; namely the effect on

(1) Headlight beams of variations in light-center length in the lamp bulbs, or improper location in the reflector
(2) Headlight beams of variations in axial alignment in the lamp bulbs, or improper location in the reflector
(3) Headlight beams of a combination of variation in light-center length and axial alignment of the headlight bulbs, or their location in the reflector
(4) A spotlight beam of variation in filament position in a headlight bulb, or location in the reflector
(5) Headlight beams of mandrel size or coil diameter of headlight filament
(6) Spotlight beams of mandrel size
(7) Spotlight beams of auxiliary bulb image

In making the measurements, the test reflector with the universal focusing-device was mounted on a rotatable table, graduated in degrees, 25 ft. from the screen having the Illuminating Engineering Society's headlight-specification test-points plotted on it. Photometric readings were taken with a Macbeth illuminometer. The headlight lamps were operated at exactly 21 mean spherical cp.

A single reflector was used; hence, in comparing the actual readings obtained with the Illuminating Engineering Society's specifications, the Illuminating Engineering Society's readings should be divided by 2. This has been done in the charts to make the figures more readily comparable. We realize that this method does not give the exact figure that would be obtained from a pair of head-lamps but, for purposes of comparison, it was considered to offer less variation than might be expected if two head-lamps were to be adjusted each time. While the exact figures are interesting to the engineer who is making a detailed study, we believe the real value of the work, to most people, lies in the photographs. The pictures bring out clearly the need for accurately made lamps and equipment and for accurate focusing, if we are to get the headlight situation under control.

TESTING PROCEDURE

The first tests were made to determine the effect of light-center length and axial alignment on three well-known types of lens, *A*, Bausch & Lomb; *B*, Patterson; and *C*, Osgood, giving the wide, medium and narrow-spread type of distribution respectively. With the lamp filament located exactly at the focal point of the reflector, we obtained the readings at the Illuminating Engineering Society's test-points which are stated in Table 1, the distribution of the light being shown in Fig. 2 for the respective lenses.

TABLE 1—LAMP IN FOCUS

Test-Point	Bausch & Lomb Lens	Patterson Lens	Osgood Lens
D	393	393	393
C	437	525	812
A	2,187	1,437	1,563
B	8,125	7,187	7,500
Pl	14,680	10,810	3,875
Pr	15,437	10,810	3,437
Ql	4,062	2,125	3,125
Qr	4,375	1,500	3,500

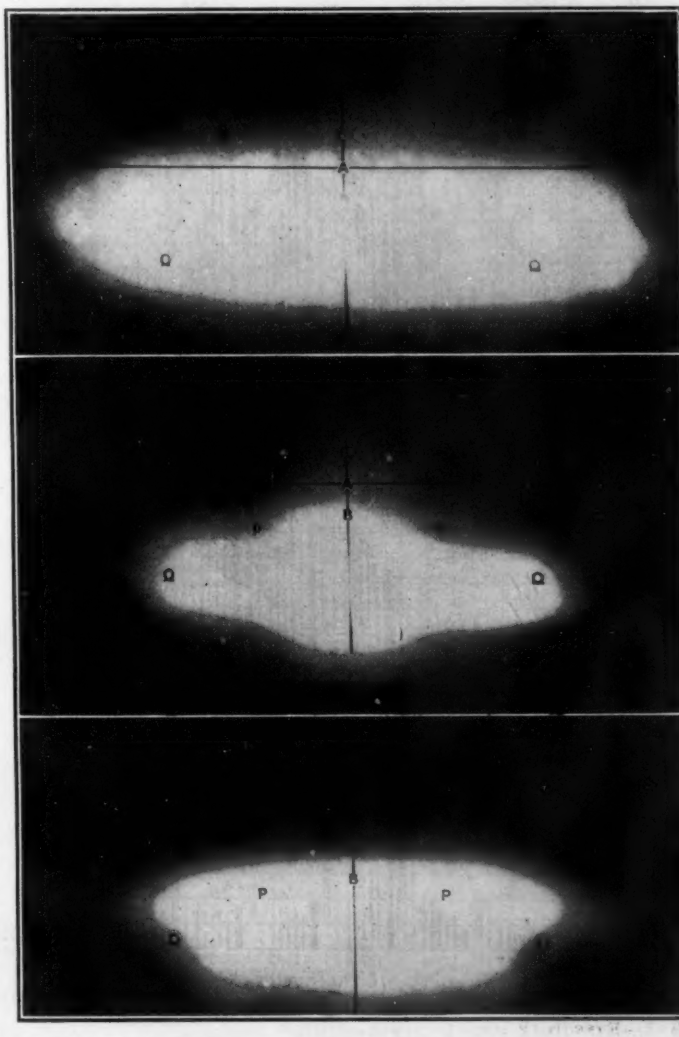

FIG. 2—EFFECT OF LIGHT-CENTER LENGTH AND AXIAL ALIGNMENT ON THREE TYPES OF LENS
Wide, Medium and Narrow-Spread Types of Light Distribution Are Provided Respectively by the Bausch & Lomb Lens Used To Obtain the Top View, the Patterson Lens Employed for the Middle View and the Osgood Lens for the View at the Bottom. With the Lamp Filament Located Exactly at the Focal Point of the Reflector, the Readings Stated in Table 1 Were Obtained at the Illuminating Engineering Society's Test-Points

TABLE 2—LAMP MOVED BACK OF THE FOCAL POINT IN 1/64-IN. STEPS

Test-Point	1/64 In.	2/64 In.	3/64 In.	4/64 In.	5/64 In.
Bausch & Lomb Lens					
D	606	1,062	1,750	2,375	2,875
C	606	1,187	1,750	2,437	3,125
A	2,625	3,750	5,000	5,375	5,875
B	10,000	8,750	9,375	7,812	6,875
Pl	12,350	11,562	9,375	7,500	5,625
Pr	11,562	12,350	9,687	7,812	5,625
Ql	4,000	4,625	4,625	4,375	3,750
Qr	3,875	4,125	4,062	3,875	3,687
Patterson Lens					
D	482	581	875	1,562	2,125
C	625	706	1,188	2,062	3,062
A	2,375	3,062	4,500	5,562	4,687
B	7,500	9,375	10,000	10,000	9,375
Pl	10,000	11,562	9,250	8,750	5,687
Pr	10,800	10,000	10,000	9,062	6,000
Ql	1,625	1,437	1,375	1,312	1,312
Qr	1,375	1,312	1,188	937	1,125
Osgood Lens					
D	412	462	481	537	631
C	937	875	1,062	1,500	1,875
A	2,187	2,500	3,187	3,875	4,375
B	5,625	6,562	6,062	6,250	6,062
Pl	2,750	3,250	2,812	3,125	3,062
Pr	2,625	3,000	2,687	3,062	3,062
Ql	3,750	3,875	2,875	2,687	2,062
Qr	3,250	3,125	2,687	2,437	1,875

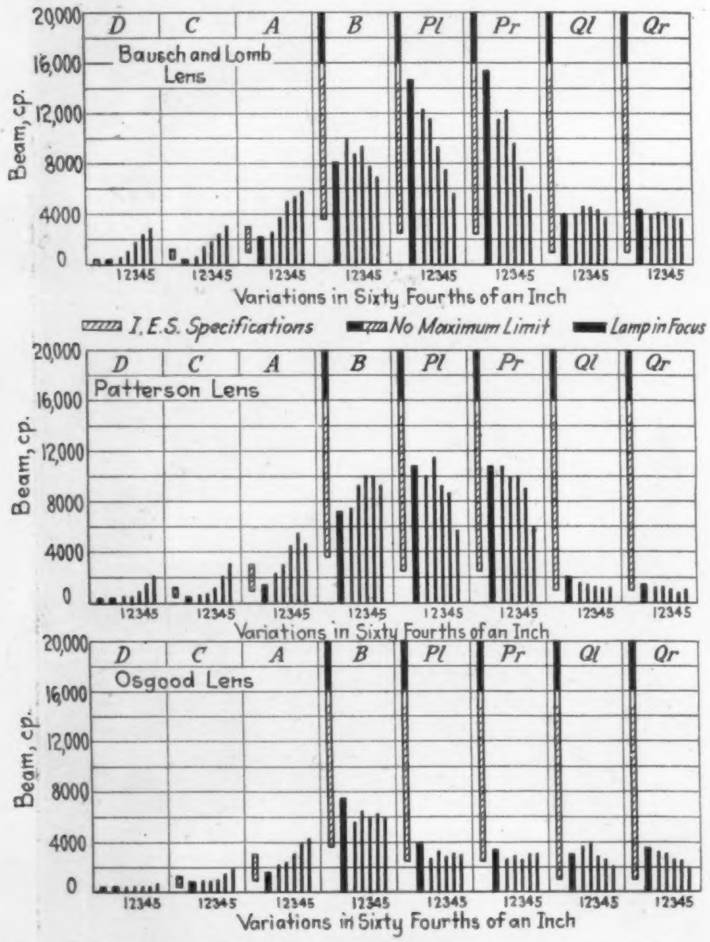

FIG. 3—EFFECTS WHEN THE LAMP IS MOVED BACK OF THE FOCAL POINT

Moving the Lamp Back of the Focal Point in Steps of 1/64 In. Produced the Readings Illustrated in the Above Charts for the Respective Lenses, the Results Being Stated Also in Table 2

The figures are shown graphically on each chart by the wide solid-columns. At the side of these columns are shown one-half the Illuminating Engineering Society's specifications in cross-hatched columns, the maximum and the minimum values being shown by the top and the

TABLE 3—LAMP MOVED AHEAD OF THE FOCAL POINT IN 1/64-IN. STEPS

Test-Point	1/64 In.	2/64 In.	3/64 In.	4/64 In.	5/64 In.
Bausch & Lomb Lens					
D	406	506	937	1,187	1,562
C	531	687	1,000	1,312	1,875
A	2,125	2,062	3,937	3,750	4,062
B	7,812	8,125	8,750	8,750	7,812
Pl	15,437	13,125	16,187	13,125	10,812
Pr	16,187	13,900	13,125	13,900	12,350
Ql	4,625	3,750	4,000	3,750	4,000
Qr	4,125	4,625	4,375	4,000	4,625
Patterson Lens					
D	368	425	387	462	687
C	493	581	593	687	1,062
A	1,187	1,312	1,625	2,187	2,937
B	6,562	5,562	6,437	6,250	6,125
Pl	8,500	9,250	8,125	7,812	9,062
Pr	9,375	10,000	7,812	6,437	7,500
Ql	2,875	2,875	2,937	3,687	4,000
Qr	1,937	2,437	3,000	3,187	3,437
Osgood Lens					
D	306	375	419	494	556
C	750	937	1,187	1,625	2,250
A	1,687	2,312	2,812	4,437	5,625
B	5,125	7,187	7,500	8,750	8,437
Pl	2,375	3,500	3,812	4,000	4,625
Pr	2,812	3,187	2,937	3,875	4,125
Ql	2,500	2,875	2,625	2,437	2,187
Qr	3,437	3,312	3,125	2,750	2,750

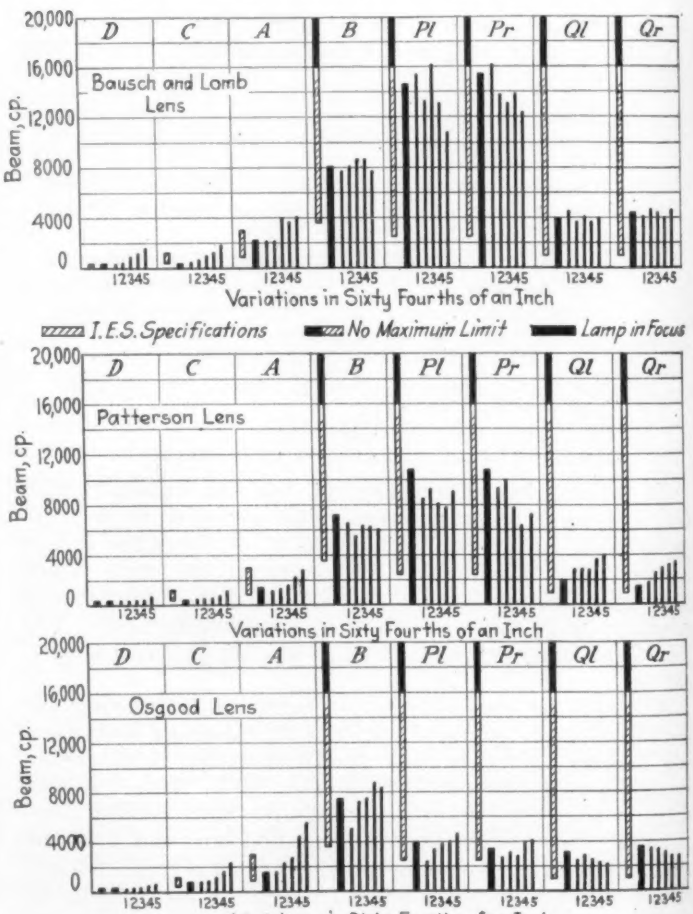

FIG. 4—EFFECTS WHEN THE LAMP IS MOVED AHEAD OF THE FOCAL POINT

The Charts Show That Moving the Light Source Ahead of the Focal Point Causes the Maximum Values at the Test-Points To Be Exceeded, But That the Light Source Must Be Moved Somewhat Farther Ahead of Than Behind the Focus before This Results

TABLE 4—LAMP MOVED VERTICALLY ABOVE THE FOCAL POINT IN 1/64-IN. STEPS

Test-Point	1/64 In.	2/64 In.	3/64 In.	4/64 In.	5/64 In.
			Bausch & Lomb Lens		
D	375	344	312	269	281
C	425	387	375	325	368
A	1,625	1,625	1,437	1,125	1,125
B	6,250	4,125	3,937	3,000	2,812
Pl	8,750	6,250	5,000	4,062	3,437
Pr	9,375	6,875	4,875	4,375	3,875
Ql	5,625	7,500	8,437	6,875	6,125
Qr	5,750	7,500	8,125	6,875	6,125
			Patterson Lens		
D	375	306	281	275	268
C	544	406	369	375	331
A	1,187	875	750	800	681
B	5,062	2,937	3,250	3,062	2,500
Pl	6,750	5,187	4,375	3,812	3,125
Pr	8,062	5,625	4,750	3,937	3,312
Ql	2,937	3,375	3,500	3,062	2,437
Qr	2,750	2,812	2,937	2,312	2,062
			Osgood Lens		
D	344	294	250	225	225
C	812	687	606	556	531
A	937	1,125	1,062	875	875
B	4,875	3,000	3,125	2,500	2,687
Pl	2,125	1,750	1,500	1,375	1,312
Pr	1,937	1,625	1,500	1,125	1,312
Ql	2,312	2,312	2,312	1,375	1,187
Qr	2,812	2,312	1,625	1,250	1,250

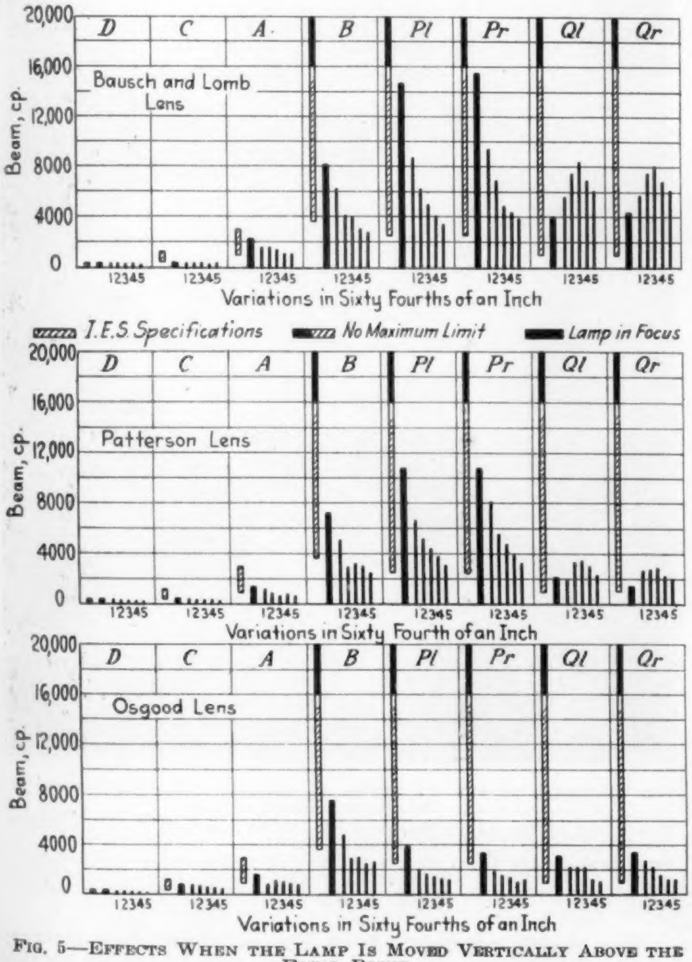

FIG. 5—EFFECTS WHEN THE LAMP IS MOVED VERTICALLY ABOVE THE FOCAL POINT

Movement of the Light Source Above the Focus in Steps of 1/64 In. Produced the Results Shown in the Above Charts

bottom of the columns respectively. Where no maximum value is specified, the top of the column is filled-in solid. The lamp was then moved back of the focal point, in steps of 1/64 in. at a time, and readings were taken at the test-points. These results are shown in Table 2 and in the charts reproduced in Fig. 3 for the respective lenses.

TABLE 5—LAMP MOVED VERTICALLY BELOW THE FOCAL POINT IN 1/64-IN. STEPS

Test-Point	1/64 In.	2/64 In.	3/64 In.	4/64 In.	5/64 In.
			Bausch & Lomb Lens		
D	531	937	1,750	2,812	5,375
C	606	1,312	2,010	3,750	6,250
A	3,125	5,937	9,375	12,350	12,350
B	12,500	18,615	17,750	13,900	10,812
Pl	12,294	17,000	12,350	9,250	6,875
Pr	20,170	17,000	10,000	10,000	6,250
Ql	2,625	2,437	2,125	1,875	1,875
Qr	3,437	2,375	2,187	1,750	1,750
			Patterson Lens		
D	519	750	1,062	2,125	4,000
C	606	1,062	1,687	3,125	6,000
A	1,937	4,375	6,437	10,312	10,625
B	10,000	14,600	15,437	14,662	11,575
Pl	13,900	13,125	11,562	11,062	10,000
Pr	13,900	14,600	13,125	10,812	9,250
Ql	1,875	1,312	1,062	1,187	1,000
Qr	1,062	750	1,062	750	937
			Osgood Lens		
D	462	531	644	713	937
C	1,187	1,312	2,062	2,812	3,687
A	2,625	3,937	5,000	5,812	7,750
B	9,625	10,375	13,125	17,000	15,437
Pl	5,312	6,875	9,250	9,437	9,250
Pr	3,812	6,437	8,750	10,437	9,062
Ql	3,312	2,687	1,562	937	937
Qr	3,875	2,437	1,437	937	1,000

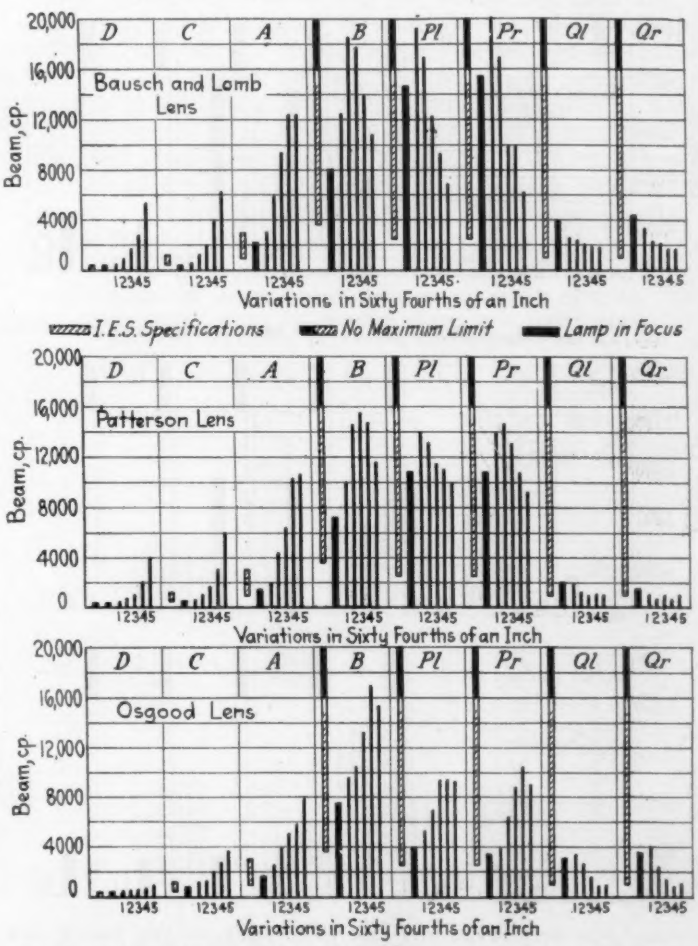

FIG. 6—EFFECTS WHEN THE LAMP IS MOVED VERTICALLY BELOW THE FOCAL POINT

Movement of the Light Source Below the Focus in Steps of 1/64 In. Produced the Results Shown in the Above Charts for the Respective Lenses

TABLE 6—LAMP MOVED SIDEWAYS FROM THE FOCAL POINT IN 1/64-IN. STEPS

Test-Point	1/64 In.	2/64 In.	3/64 In.	4/64 In.	5/64 In.
	Bausch & Lomb Lens				
D	363	406	406	363	438
C	469	469	456	531	556
A	1,875	1,875	1,937	2,125	2,812
B	7,812	7,500	8,125	8,437	7,812
Pl	11,575	11,575	10,800	9,275	9,375
Pr	11,575	11,575	10,800	11,575	10,000
Ql	3,437	4,125	4,000	3,187	3,250
Qr	4,875	6,250	4,750	6,250	6,250
	Patterson Lens				
D	363	369	363	325	306
C	525	400	469	531	512
A	1,375	1,562	1,562	1,875	2,010
B	5,750	7,312	7,187	7,875	6,375
Pl	9,062	9,625	9,125	7,687	6,250
Pr	10,500	11,575	11,250	10,812	10,625
Ql	1,250	1,125	875	812	656
Qr	2,375	3,500	5,375	6,437	7,187
	Osgood Lens				
D	419	319	356	312	294
C	937	937	1,062	937	875
A	2,062	2,250	2,010	1,937	2,010
B	6,625	7,187	6,562	5,312	5,062
Pl	2,875	2,750	3,437	2,812	2,562
Pr	3,187	4,375	6,562	8,187	9,187
Ql	3,437	2,687	2,812	2,062	1,562
Qr	3,625	4,687	5,500	5,562	5,312

It is evident from the charts that a very slight movement of the light source, back of the focus, causes the beam to exceed the maximum limits at points *B*, *C* and *A* and, with lens *B*, the minimum value required at point *Qr* is just barely met. The lamp was then returned to the focal point and moved ahead of it 1/64 in. at a time, with the results given in Table 3.

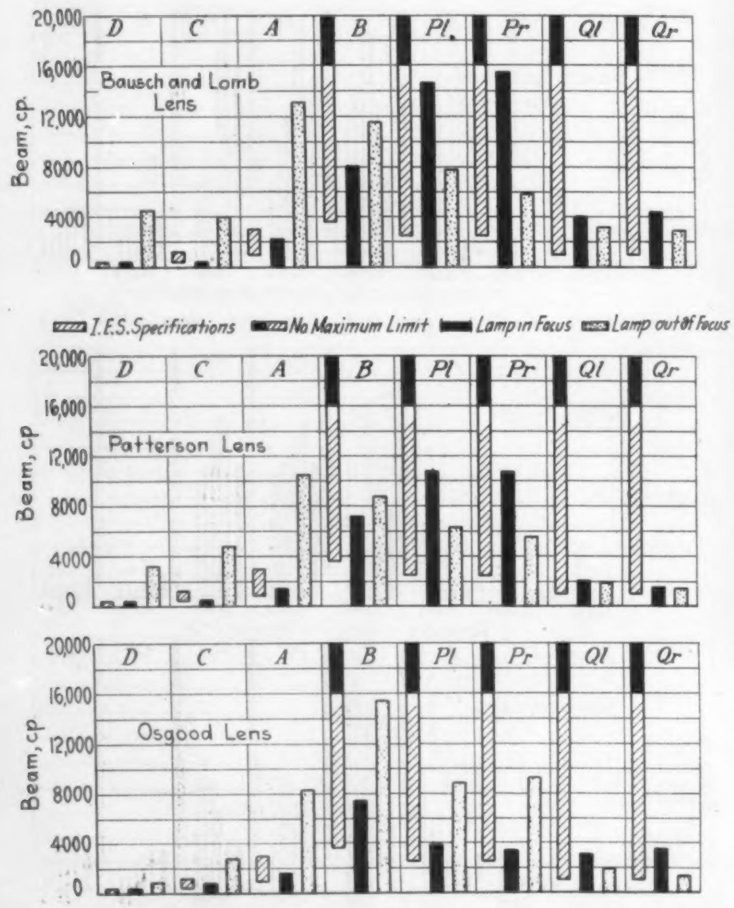

FIG. 7—EFFECTS OF MOVING THE LAMP BACK OF AND BELOW THE FOCAL POINT

When the Lamp Was Moved 3/64 In. Behind the Focal Point and Then Was Moved 3/64 In. Below That Position, Not Only Were the Glare Limits Greatly Exceeded But the Road Illumination Was Reduced Seriously. This Is Illustrated in Fig. 8 and the Other Data Are Presented in Table 7 for the Respective Lenses

TABLE 7—LAMP MOVED 3/64 IN. BEHIND THE FOCAL POINT AND THEN 3/64 IN. BELOW THAT POSITION

Lens / Test-Point	*Bausch & Lomb*	*Patterson*	*Osgood*
D	4,500	3,187	937
C	4,000	4,750	2,812
A	13,125	10,562	8,250
B	11,575	8,750	15,437
Pl	7,812	6,250	8,875
Pr	5,875	5,625	9,312
Ql	3,250	1,875	1,875
Qr	2,875	1,437	1,250

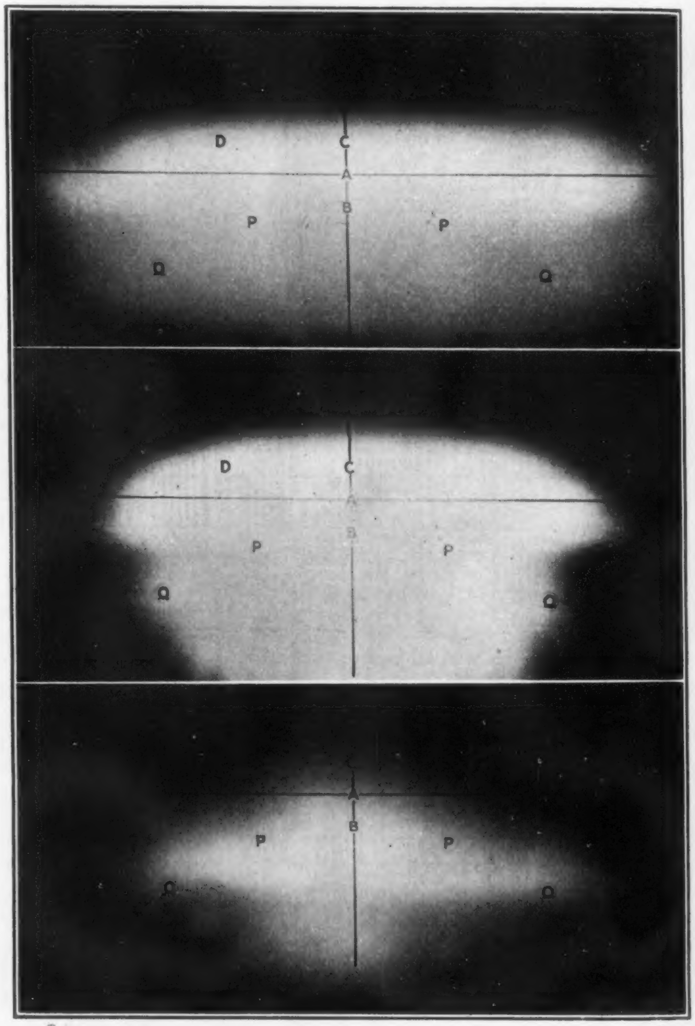

FIG. 8—ILLUMINATION PRODUCED BY MOVING THE LAMP BACK OF AND BELOW THE FOCAL POINT

Movement of the Light Source 3/64 In. Behind and 3/64 In. Below the Focal Point Gave the Results Shown in the Top View for the Bausch & Lomb Lens, in the Middle View for the Patterson Lens and in the Bottom View for the Osgood Lens. Other Information Pertaining to This Procedure Is Presented in Fig. 7 and in Table 7

The charts reproduced as Fig. 4 show that moving the light source ahead of the focus also exceeds the maximum values at points *B*, *C*, and *A*, but the source has to be moved somewhat farther ahead than behind the focus before this results. Apparently, lens *B* is the least sensitive of the three in this respect, as the maximum is exceeded only at point *D*, and here only when the source is 4/64 in. ahead of the focal point. Returning

TABLE 8—LAMP MOVED BACK OF THE FOCAL POINT IN 1/64-IN. STEPS, BUT TILTED TO COMPLY WITH ILLUMINATING ENGINEERING SOCIETY'S SPECIFICATIONS AT POINT *D*

Test-Point	1/64 In.	2/64 In.	3/64 In.	4/64 In.	5/64 In.
		Bausch & Lomb Lens			
D	394	394	394	394	394
C	531	406	406	394	406
A	2,187	1,875	1,562	1,562	1,562
B	6,875	6,250	4,750	4,125	3,750
Pl	10,812	7,500	6,187	5,937	4,625
Pr	10,000	7,187	5,625	5,562	5,000
Ql	6,875	6,875	4,875	3,875	3,750
Qr	6,500	6,875	5,562	4,500	3,687
		Patterson Lens			
D	394	394	394	394	394
C	500	513	475	506	519
A	1,625	1,687	1,562	2,187	2,010
B	6,875	5,937	6,250	5,437	5,625
Pl	10,000	9,562	7,500	6,875	6,187
Pr	10,000	9,187	8,625	6,625	6,500
Ql	1,812	2,062	2,187	2,312	2,250
Qr	1,750	1,812	2,375	2,750	2,875
		Osgood Lens			
D	394	394	394	394	394
C	875	1,000	1,000	1,125	1,250
A	1,750	1,937	2,562	3,062	3,000
B	4,687	5,125	6,375	6,875	7,500
Pl	2,687	3,062	3,250	3,125	3,562
Pr	1,875	2,437	2,562	2,937	3,250
Ql	4,000	4,125	3,312	2,750	2,125
Qr	3,312	3,375	2,500	2,312	1,750

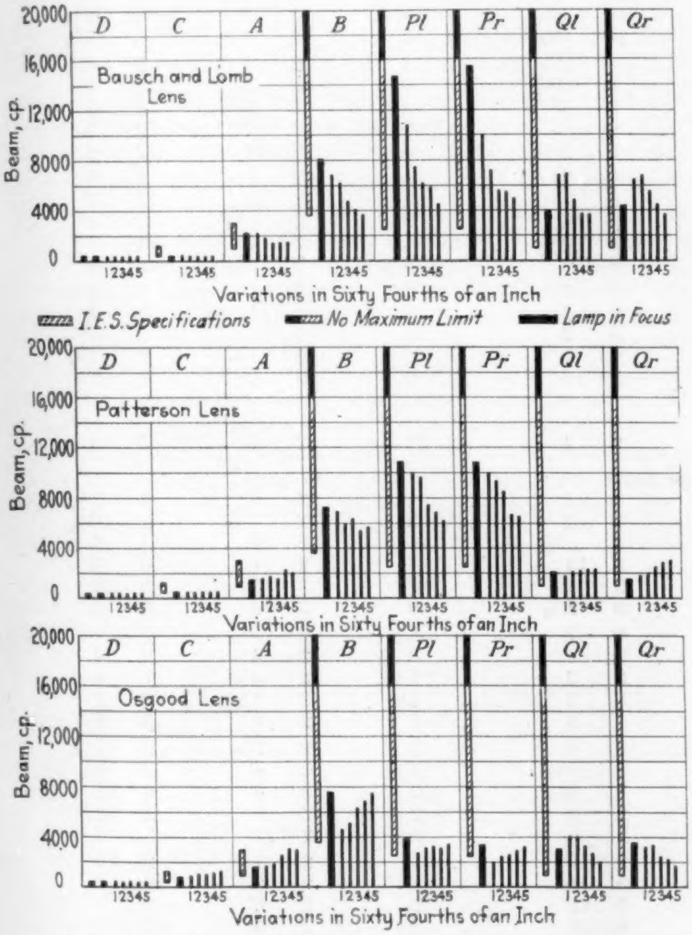

FIG. 9—EFFECTS OF MOVEMENT OF THE LAMP WHEN TILTED
The Lamp Was Moved Back of the Focal Point in Steps of 1/64 In. But Was Tilted To Comply with the Illuminating Engineering Society's Specification at Test-Point *D*

again to the focal point, the lamp was moved vertically above the focus, with the results shown in Table 4 and Fig. 5, for the respective lenses.

Moving above the focus, of course, throws the beam down, and the converse is true when the filament is moved below the focus. The latter movement, however, is more serious, as it increases the candlepower at the glare point very rapidly. The charts of Fig. 5 show the values as the filament goes up. Once again the lamp was returned to the focus, and then moved vertically downward to obtain the data given in Table 5 and Fig. 6 for the respective lenses.

The charts of Fig. 6 show that if the filament is moved but 1/64 in. below the focus, the glare value at point *D* is exceeded. Again returning to the focus, the lamp was moved sideways from the focal point in 1/64-in. steps. The results are shown in Table 6.

Moving the filament sideways does not affect either the glare-point values or those at *A* and *B* materially, but it does shift the entire beam sideways.

To determine what happened with a lamp that just came within the lamp manufacturers' present maximum-variation tolerance of 3/64 in., as to both light-center length and axial alignment, the lamp was returned to the focal point. Then it was moved 3/64 in. behind the focal point, and then 3/64 in. vertically below that position. The results are shown in chart form in Fig. 7 for the respective lenses. Not only are the glare limits greatly exceeded, but the road illumination is seriously reduced as shown in Fig. 8. The results are presented in Table 7 for the respective lenses.

We often had heard it stated that if a lamp were out of focus, all that needed to be done to make a good driving light of it was to tilt the head-lamp until the beam ceased to be excessively glaring, taking the Illuminating Engineering Society's limit of 800 cp. as that condition. To determine this, the lamp was again returned to focus and moved back of the focal point 1/64 in. at a time, but at each setting of the beam it was tilted down until it came within the Illuminating Engineering Society's specification at point *D*, or rather one-half of it, as only one lamp was used. The measurements

TABLE 9—LAMP MOVED BELOW THE FOCAL POINT IN 1/64-IN. STEPS, BUT TILTED TO COMPLY WITH THE ILLUMINATING ENGINEERING SOCIETY'S SPECIFICATIONS

Test-Point	1/64 In.	2/64 In.	3/64 In.	4/64 In.	5/64 In.
		Bausch & Lomb Lens			
D	394	394	394	394	394
C	413	469	506	438	456
A	1,812	2,125	2,125	1,562	1,687
B	8,750	9,687	10,800	8,437	6,500
Pl	16,200	15,125	17,000	12,350	10,000
Pr	17,000	14,650	15,437	13,125	9,275
Ql	4,375	5,500	3,750	5,250	5,875
Qr	4,500	4,125	5,375	5,750	6,562
		Patterson Lens			
D	394	394	394	394	394
C	512	506	531	531	525
A	1,437	1,250	1,312	1,500	1,625
B	8,750	5,687	6,187	5,312	4,937
Pl	11,575	10,000	9,375	6,500	6,562
Pr	13,900	9,687	8,437	8,125	6,125
Ql	1,500	2,062	2,375	2,187	3,062
Qr	1,562	1,750	2,312	2,687	2,687
		Osgood Lens			
D	394	394	394	394	394
C	937	937	937	750	812
A	1,562	1,375	1,437	1,187	1,187
B	4,250	3,125	3,437	1,937	2,250
Pl	2,062	1,937	1,937	1,375	1,562
Pr	1,875	1,562	1,562	1,000	1,250
Ql	4,500	3,500	4,187	2,437	2,500
Qr	3,750	3,500	5,000	1,187	1,562

taken are shown in Table 8 and Fig. 9 for the respective lenses.

The charts show that, by this procedure, legal beams can be obtained, but at considerable loss in road illumination, except in the case of lens *C*, by which the intensity on the center of the road is increased somewhat. Next, the same procedure was repeated, but by moving the lamp below the focus instead of back of it. The results are shown in Table 9. In this case, the results are fairly good for lenses *A* and *B*, but poor for lens *C*, the minimum values at points *B* and *P* not being complied with.

At the same time that the photometric readings were taken, measurements were made of the height and width of the beams, and their relative positions, or shift of positions from the normal, obtained with the lamp at the focus. This was done by making a horizontal reference-line on the screen at the same height as the center of the headlight, and a vertical line passing through the axis of the head-lamp. Linear measurements were then made to the top, bottom and edge of the beams from these reference lines. The results are given in Table 10.

Filament Location in Spotlights

A study was then made to determine the effect of filament location on spotlights. For this purpose, the standard test-reflector was masked-down to an opening of 4½ in. to be comparable with spotlights. We realize

TABLE 10—HEIGHT, WIDTH AND RELATIVE POSITIONS OF BEAMS WITH LAMP AT THE FOCUS

Position	In.	Edge of Beam: Left of Reference Line, Ft.	Left of Reference Line, In.	Right of Reference Line, Ft.	Right of Reference Line, In.	Total Width at 25 Ft., Ft.	Total Width at 25 Ft., In.	Top of Reference Line, Ft.	Top of Reference Line, In.	Bottom of Reference Line, Ft.	Bottom of Reference Line, In.	Total Height at 25 Ft., Ft.	Total Height at 25 Ft., In.
Bausch & Lomb Lens													
Lamp in Focus		4	7	4	4	8	11	..	5	1	10	2	3
Back of Focus	1/64	4	8	4	4	9	0	..	5	2	½	2	5½
	2/64	4	11½	4	4	9	3½	..	6½	2	1½	2	8
	3/64	5	1	4	5	9	6	..	7½	2	4½	3	0
	4/64	5	5	4	5½	9	10½	..	11	2	7½	3	6½
	5/64	5	6	4	6½	10	½	1	3	2	10½	4	1½
Ahead of Focus	1/64	5	0	4	7	9	7	..	4	1	11½	2	3½
	2/64	5	3	4	9	10	0	..	7	2	2	2	9
	3/64	5	3	4	10	10	1	..	7½	2	4½	3	0
	4/64	5	3	5	½	10	5½	..	9½	2	5	3	2½
	5/64	5	8	5	½	10	6½	1	0	2	7½	3	7½
Above Focus	1/64	4	9½	4	5	9	2½	..	3	2	1	2	4
	2/64	5	½	4	5	9	5½	..	3	2	2	2	5
	3/64	5	2	4	5	9	7	..	4	2	3	2	7
	4/64	5	2	4	6	9	8	..	5	2	7	3	0
	5/64	5	2	4	6½	9	8½	..	5	2	11	3	4
Below Focus	1/64	4	9	4	4	9	1	..	4	2	1	2	5
	2/64	4	10	4	3½	9	1½	..	7	2	0	2	7
	3/64	5	1	4	3	9	4	..	9½	2	½	2	10
	4/64	5	1½	4	3	9	4½	1	1	2	1	3	2
	5/64	5	0	4	3	9	3	1	3½	2	2½	3	6
Sideways from Focus	1/64	4	10	4	5	9	3	..	3½	2	0	2	3½
	2/64	4	8	4	7	9	3	..	5	1	11	2	4
	3/64	4	6	4	9	9	3	..	6	1	11	2	5
	4/64	4	6	5	1	9	7	..	7	2	½	2	7½
	5/64	4	6	5	4	9	10	..	8	2	1	2	9
3/64 In. Back of and 3/64 In. Below Focus		4	10	4	6	9	4	..	11	2	5	3	4
Patterson Lens													
Lamp in Focus		3	11	4	5	8	4	..	1½	2	6	2	7½
Back of Focus	1/64	3	11	4	3	8	2	..	3	2	7½	2	10½
	2/64	4	0	4	½	8	½	..	5	2	8	3	1
	3/64	4	4	4	7	8	11	..	7	2	10	3	5
	4/64	4	5½	4	7½	9	1	..	8	3	2	3	10
	5/64	4	5½	4	9	9	2½	1	0	3	4	4	4
Ahead of Focus	1/64	3	10	4	5	8	3	..	1½	2	5½	2	7
	2/64	3	11	4	5	8	4	..	0	2	4	2	4
	3/64	3	11	4	4	8	3	..	1½	2	4½	2	6
	4/64	3	10½	4	4½	8	3	..	4½	2	7½	3	0
	5/64	4	2	4	6	5	8	..	6	2	8	3	2
Above Focus	1/64	3	7	3	11	7	6	..	2	2	5½	2	7½
	2/64	3	9½	4	1	7	10½	..	2	2	4	2	6
	3/64	3	11	3	9½	7	8½	..	2	2	6	2	8
	4/64	3	11	3	6	7	5	..	2	2	9	2	11
	5/64	4	0	3	9	7	9	..	1	2	11	3	0
Below Focus	1/64	3	10	4	1	7	11	..	3	2	7	2	10
	2/64	4	3	4	2	8	5	..	5	2	8	3	1
	3/64	3	4	3	7	6	11	..	7	2	6	3	1
	4/64	3	5	3	6	6	11	..	8	2	5	3	1
	5/64	3	9	3	7	7	4	..	11	2	5	3	4
Sideways from Focus	1/64	3	7	4	2	7	9	..	2	2	5½	2	7½
	2/64	3	6	4	4	7	10	..	2½	2	6	2	8½
	3/64	3	4	4	6	7	10	..	3	2	6½	2	9½
	4/64	3	2	4	9	7	11	..	3	2	7	2	10
	5/64	3	0	5	1	8	1	..	4	2	11	3	3
3/64 In. Back of and 3/64 In. Below Focus		4	4	4	6	8	10	1	1	2	11	4	0

TABLE 10—HEIGHT, WIDTH AND RELATIVE POSITIONS OF BEAMS WITH LAMP AT THE FOCUS—(*Concluded*)

Osgood Lens

		Edge of Beam											
		Left of Reference Line		Right of Reference Line		Total Width at 25 Ft.		Top of Reference Line		Bottom of Reference Line		Total Height at 25 Ft.	
Position	In.	Ft.	In.	Ft.	In.	Ft.	In.	Ft.	In.	Ft.	In.	Ft.	In.
Lamp in Focus		3	2	3	2	6	4	..	3	2	2	2	5
Back of Focus	1/64	3	3	3	3	6	6	..	4	2	2	2	6
	2/64	3	5	3	4	6	9	..	6	2	3	2	9
	3/64	3	11	3	6	7	5	..	9	2	6	3	3
	4/64	3	7	3	7½	7	2½	..	9½	2	7½	3	5
	5/64	3	9	3	8	7	5	1	1	2	9	3	10
Ahead of Focus	1/64	4	4	3	9	8	1	..	6	2	6	2	10
	2/64	4	4	3	11	8	3	1	0	2	3	3	3
	3/64	4	1	3	10	7	11	..	9	2	9	3	6
	4/64	4	2	3	10	8	0	..	11	2	10	3	9
	5/64	4	8	4	2	8	10	..	11½	2	10½	3	10
Above Focus	1/64	4	0	3	5	7	5	..	5½	2	3½	2	9
	2/64	3	11	3	5	7	5	..	7	2	5	2	10
	3/64	4	3	3	7½	7	10½	..	8	2	10	3	6
	4/64	4	2	3	7	7	9	..	10	2	11	3	9
	5/64	3	11	3	7	7	6	..	9	2	10	3	7
Below Focus	1/64	3	10	3	6	7	4	..	4½	2	1½	2	6
	2/64	3	10	3	6	7	4	..	9	2	1	2	10
	3/64	4	3	3	4	7	7	..	9½	2	½	2	10
	4/64	4	3	3	7	7	10	..	10	2	1	2	11
	5/64	3	11	3	6	7	5	1	1½	2	3½	3	5
Sideways from Focus	1/64	3	4½	3	6	6	10½	..	3	2	4	2	7
	2/64	3	2½	3	8	6	10½	..	3½	2	4½	2	8
	3/64	3	0	3	10½	6	10½	..	4½	2	5½	2	10
	4/64	2	11	3	9	6	8	..	8	2	2	2	10
	5/64	2	10	3	10	6	8	..	8½	2	4½	3	2
3/64 In. Back of and 3/64 In. Below Focus		2	7	3	10½	6	5½	..	11	2	8	3	7

that some spotlights have shorter focal-lengths than the 1¼-in. focal-length of our test reflector. It was felt, however, that this would have very little bearing on the test results, distortion of beam and the like, although it might add slightly to the spread of the beam. It was observed that a dark area appeared in the beam as the lamp was thrown out of focus sufficiently; however, these areas were only relatively dark, having about 20,000 cp. directed to them. Candlepower measurements were taken in this area, as well as in the brightest portion of the beam, wherever that happened to come. As the filament was moved sideways from the axis, the beam became elliptical; hence, both maximum and minimum diameters were measured, as well as the distance the center of the beam was thrown off from the axis at 25 ft. A test was made also to show the effect of a lamp having its filament at the limits of present manufacturing tolerances; that is, 3/64 in. off the axis and 3/64 in. short in light-center length. Short, rather than long light-center length was chosen, because the distortion is greater from short light-center length than from long light-center length. The results of these tests are shown in Table 11.

To study the effect on the beam of a spotlight having a light source made with a filament wound on a large mandrel, No. 15, outside coil-diameter 0.029 in. and length 0.085 in., as compared to one wound on a small mandrel, No. 10, outside coil-diameter 0.024 in. and length 0.098 in., horizontal and vertical distribution-curves were obtained using a lamp of each type. These showed a beam diameter at 25 ft. of 21 in. for the large mandrel and 26 in. for the small mandrel. The maximum

TABLE 11—SPOTLIGHT WITH LARGE-MANDREL LAMP-FILAMENT

Position	In.	Maximum Reading, Cp.	Dark Spot Reading, Cp.	Maximum Diameter at 25 Ft. In.	Minimum Diameter at 25 Ft. In.	Distance Center of Beam Is Thrown Sideways In.
Lamp in Focus		86,906	.....	21	21	0
Ahead of Focus	1/64	72,562	.....	23	23	0
	2/64	54,800	34,731	29	29	0
	3/64	42,450	21,594	32	32	0
	4/64	26,250	7,500	37	37	0
	5/64	16,206	3,125	41	41	0
Back of Focus	1/64	63,837	.....	26	26	0
	2/64	42,450	.....	31	31	0
	3/64	20,837	.....	36½	36½	0
	4/64	12,812	5,875	40	40	0
	5/64	11,875	1,625	47	47	0
Sideways from Focus	1/64	77,187	.....	22	20	1½
	2/64	80,275	41,684	26	21½	3½
	3/64	77,187	.....	29	24	6
	4/64	61,750	.....	31	26	7½
	5/64	43,225	.....	34	26	10
3/64 In. Sideways from, and 3/64 In. Back of Focus		34,731	5,500	42	37	5

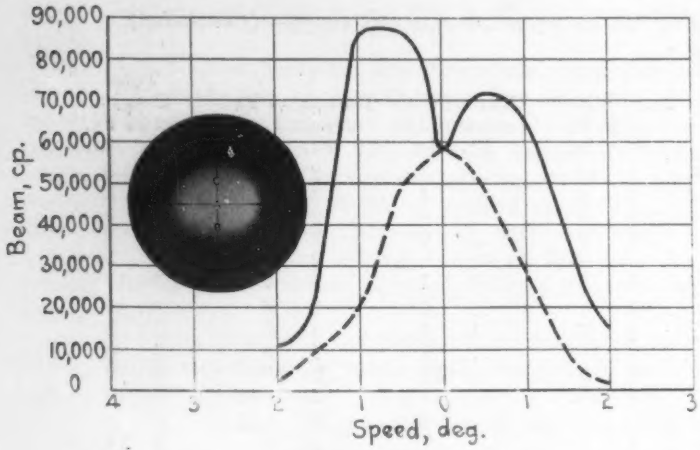

FIG. 10—EFFECTS OF FILAMENT SIZE ON SPOTLIGHT BEAMS
Curves and the Light Spot Obtained from the Large-Mandrel Lamp-Filament Are Shown

beam intensities were 88,000 and 75,500 cp. respectively. Figs. 10 and 11 respectively show the results obtained. The two humps in the horizontal curve are caused by the two filament-coils, each located close to the focal point of the reflector.

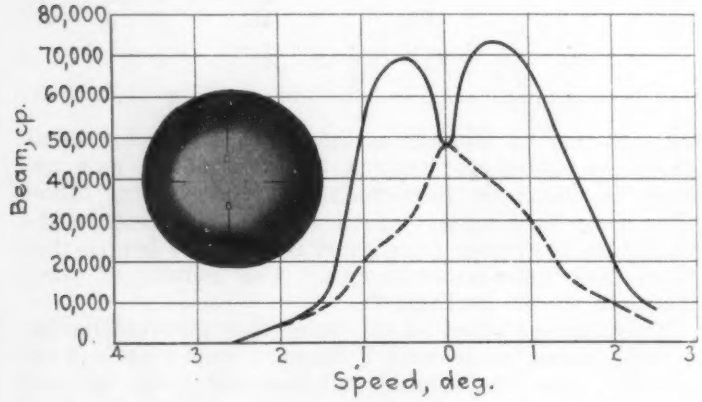

FIG. 11—EFFECTS OF FILAMENT SIZE ON SPOTLIGHT BEAMS
Curves and the Light Spot Obtained from the Small-Mandrel Lamp-Filament Are Shown

Some claims had been made that a material difference in the height or cut-off of the beam resulted from putting the plane of the filament in the headlight reflector vertically, rather than in the usual horizontal position. This was tested-out with the large and with the small-mandrel filaments. The tests showed that the mandrel of larger diameter producing a shorter stockier coil gives the more concentrated beam. As a matter of interest, the beam diameters were also measured with the lenses removed. Table 12, gives the results of these tests.

In some cases Table 12 shows a greater spread for the horizontal than for the vertical filament-position. This does not seem logical, and our general conclusions are

TABLE 12—HEADLIGHT-BEAM MEASUREMENTS

Type of Lens	Filament Position	Distance from Top of Beam to Reference Line, In.	Distance from Bottom of Beam to Reference Line, In.	Total Vertical Spread at 25 Ft., In.
Bausch & Lomb				
Large Mandrel	Horizontal	4½	24	28½
	Vertical	2	20	22
Small Mandrel	Horizontal	4	25	29
	Vertical	4	25	29
Patterson				
Large Mandrel	Horizontal	1	25	26
	Vertical	4½	24	28½
Small Mandrel	Horizontal	8	25	33
	Vertical	2½	24½	27
Osgood				
Large Mandrel	Horizontal	4½	24	28½
	Vertical	4½	27	31½
Small Mandrel	Horizontal	3	24	27
	Vertical	3	28½	31½

Size of Spots Without Lenses
Large Mandrel, 22½ In.
Small Mandrel, 24½ In.

that, due to the difficulty of determining the exact edge of the beam, we can, for all practical purposes, consider that the difference is little or none and certainly wide variations of the relation of the plane of the base pins to that of the filament will not affect the resultant beam materially.

EFFECT OF AUXILIARY BULB IMAGE

To show clearly the effect of reflected or auxiliary bulb image, and how this is broken-up by the new corrugated bulbs, the photographs reproduced in Figs. 12 and 13 were made. In Fig. 12, the view at the extreme left shows a smooth bulb with the reflected image to one side of the filament, and the adjacent left-central view shows the resultant spot. The central view shows a smooth bulb with the reflected image ahead of the filament, and the adjacent right-central view shows the resultant spot. The view at the extreme right shows the bulb image superimposed on the filament. In Fig. 13, the left view shows the spot when the corrugations on the bulb are too shallow and the strong light from the image is not completely diffused. The middle view shows the spot from a bulb in which the corrugations are too deep, each acting as a small lens. The view at the right shows the spot with a bulb image diffused by corrugations of correct proportions.

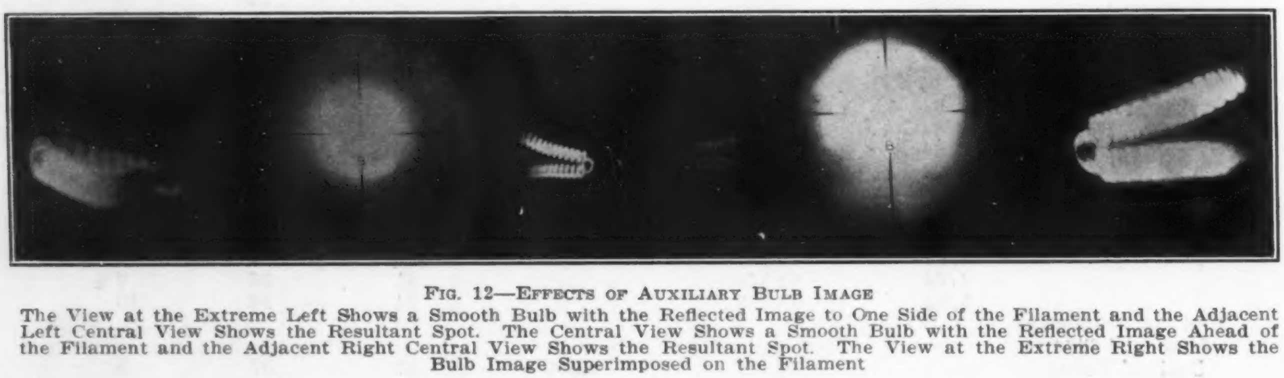

FIG. 12—EFFECTS OF AUXILIARY BULB IMAGE
The View at the Extreme Left Shows a Smooth Bulb with the Reflected Image to One Side of the Filament and the Adjacent Left Central View Shows the Resultant Spot. The Central View Shows a Smooth Bulb with the Reflected Image Ahead of the Filament and the Adjacent Right Central View Shows the Resultant Spot. The View at the Extreme Right Shows the Bulb Image Superimposed on the Filament

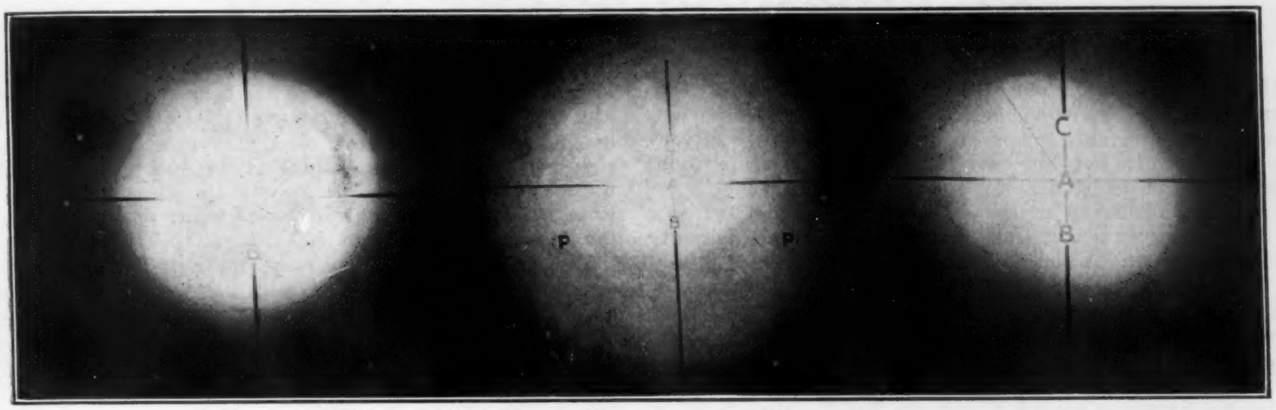

FIG. 13—EFFECTS PRODUCED BY CORRUGATED BULBS
The Left View Shows the Spot When the Corrugations on the Bulb Are Too Shallow and the Strong Light from the Image Is Not Completely Diffused. The Middle View Shows the Spot from a Bulb in Which the Corrugations Are Too Deep, Each Acting As a Small Lens. The View at the Right Shows the Spot with a Bulb Image Diffused by Corrugations of Correct Proportions

SUMMARY

Summarizing all the tests, we can say that they show clearly that the control of the flood of light from a head-lamp can be likened to the control of a gallon of water. It can be concentrated into a narrow, powerful beam, corresponding to putting the gallon of water into a deep vessel of small diameter or it can be spread out as if the water were poured into a large shallow pan. When light is taken from one point, it appears somewhere else. The area that it is to illuminate and the intensity of light on that area are controllable as are the depth of the water and the area it will cover. The control of the light depends upon accurately made equipment with light source, reflector and lens held rigidly in *exactly* the correct relation with one another. The tests indicate that a precision of $\pm$ 2/64 in. in the position of the lamp filament, with respect to the focal point of the reflector, must be maintained to secure good all-round illumination. This is not only the bulb-manufacturers' problem in producing filaments located more accurately with respect to the lamp bases, but also the problem of manufacturers of lamps in producing sockets, focusing devices and reflectors that will "stay put" within $\pm$ 2/64 in. The car-builders' problem is to mount the head-lamps accurately and the lens-manufacturers' job is to maintain accurate lenses. All this will be costly, but if the driving public is asked if it will pay \$5 more for a car having really good head-lamps, the answer "Yes" will be shouted back.

In conclusion, we wish to express our thanks to F. W. Brehme, who did the photometric work.

STEEL-MAKING

STEEL-MAKING is one of the most basic of all industries for its finished product supplies the raw material for numerous other lines to use in further manufacturing. Because of this basic nature, however, it is subject to more severe fluctuations in demand than are the industries situated nearer to the ultimate consumer. Retail trade in staple commodities enjoys a remarkable regularity and is little affected by changes in financial and business conditions, but the industries making "producers' goods" operate by fits and starts. Steel mills will be doing a rush business one season when a building boom is on or when the railroads are prosperous; then face a season during which idle plants, high overhead expenses, bond interest and similar items rapidly eat up their surplus.

The difficulty of doing business in an industry whose chief raw material fluctuates widely in price is illustrated by examining the range of quotations on pig iron over the last 5 years. For September, 1920, the composite price was \$47.83 per ton, and in the ensuing 12 months of post-war deflation declined to \$19.89. During 1922 it ranged from \$19.14 in February to \$31.78 in September; in 1923 from \$30.83 in April to \$21.40 in November; in 1924 from \$22.84 in February to \$19.31 in July; and for the current year it ranged from \$22.44 in January to \$18.96 in July.

Too much significance, however, should not be attached to pig-iron prices, because of the fact that most of the leading steel-manufacturers make their own pig iron, and many have their own iron ore mines as well. The pig iron, therefore, represents to them a partially finished product to be used in further manufacture, and the question of price changes and stocks on hand is not so important to them as it would be if they purchased all their iron in the open market. The present practice is to use scrap for approximately 50 per cent of the charge and new pig iron for the other 50 per cent. The salvaging of the old material has become a large industry in itself.

The increase in plant capacity during the last 9 years has been proportionately less than for any similar period, although it includes the 25-per cent increase during the war years 1915 to 1918. The increase in production over 5-year intervals has never been less than 30 per cent, except that 1924, a sub-normal year, shows a decrease as compared with 1920, a year above normal. The "operating ratio" during the half century has ranged between a high of 79.7 and a low of 51.0 per cent. Because of the swings incident to the business cycle, and to the carrying of idle capacity during repairs and as a reserve, an operating ratio of 60 to 80 per cent is considered satisfactory.

In 1880, when the steel industry was just establishing itself, the per capita use of steel was 56 lb., from which it increased in 1890 to 153 lb., and in 1900 to 299 lb. Since then the "age of steel" has brought a requirement of 424 lb. per capita in 1905, 557 lb. in 1910, 660 lb. in 1915, 905 lb. in 1920 and 755 lb. last year. It seems probable that 1925 will be recorded as slightly better than normal and considerably ahead of 1924.

The United States produces over half of the world's steel. Foreign producers have frequently submitted bids on American contracts this year and a limited though increasing tonnage is being imported.—National City Bank.

DE-ORGANIZING FOR WORK

THE management of one's self, which gets down to controlling one's own time and distinguishing the important from the unimportant, comes only from experience. Every man has to work out his own rules and, like all personal rules, they have to be flexible.

I never have believed in what is called "delegation." I hold that if anything in a business is wrong, the fault is squarely with management. A company must have one head and only one, and he must be the real executive head. The board of directors can advise on policies but it cannot run the business, and policies never make a business successful. There is some thought that if a number of men waste a few days drafting a policy it is the same as doing the work. A fine lot of policies are harmless enough if you can find the time to draw them up. But they are policies and nothing more.

I have great respect for the written word, but no amount of writing will take the place of action. A policy is a policy and that is all it is. And the danger always exists that a policy in effect for a long time will get into the hallowed class and the organization will regard it as inspired. A bad policy is worse than no policy at all, and policies have a way of going bad. The world changes and policies must also change. I know of only one first-class policy: Use what common sense you can under the circumstances.

Success is the sum of detail. It might perhaps be pleasing to imagine one's self beyond detail and engaged only in great things. But I have often observed that, if one attends only to great things and lets the little things pass, the great things become little—that is, the business shrinks.

It is not possible for the chief executive to hold himself aloof from anything. I thought when I started out to build an organization, and thus give myself time to plan, that I could devise a self-acting paper organization, and that, by dividing up the work and delegating the responsibility, the company would run of itself. Not all at once, but gradually, I contracted the chart fever. The first step was to departmentalize the business, which is always a fine, satisfying thing to do.

And naturally when one gets the business into departments with department heads, those heads begin to departmentalize their own departments. We never faced a duty without dividing it; I did not attempt to follow the divisions and subdivisions, for that was the duty of the vice-presidents, and under the rules of the game I was not to interfere with them.

And then, inevitably, the men began to write letters to each other. I know of no better way of fooling one's self than writing interoffice communications and asking for reports. A man can keep himself busy that way all day long and completely satisfy his conscience that he is doing something worthwhile. We wrote so many notes that the vice-presidents and their assistants and their assistants often used to get a day or two behind in the reading of them and we had to devise a bright red interoffice telegram for really urgent business.

No man will ever know how many reports came into our organization. And every one of these reports was analyzed and compared with other reports. Not one of the vice-presidents could possibly read all the reports that came to him regularly by his order. But just by looking at the pile of unread reports on his desk he had the pleasant feeling that, even if he did not know what was going on, at least he had the facts before him.

When the smash of 1920 came and half the business of the Country found itself going under, we came to our senses. The charts went out the window, we abolished offices and departments, we called for all the forms that were in use. They came in by the hundreds and with nearly every one came a note saying how essential it was. We paid no attention to the notes. We went on the principle that the form had to contain information that we could not do business without or it went out. We cut down to the bare necessities, such as shipping blanks, invoices and branch reports of the most elemental character. We reduced our statistical department from 35 people to 3, and now we can get any statistics we want, whereas before we got only reams of stuff we could not understand. We cut the office force from 1700 to 300 and found we had plenty of clerks left to do everything that needed doing. We now have no statements made up for purposes of record. The test is, are they used?

We have only one vice-president, and he is actually the vice-president; he acts for me. Our scheme can be stated thus:

> We are all doing this job together under the president and the vice-president; each man has his special duties, but they converge upon the one point of getting the job done.

This plan of management, which is hardly formal enough to be called an organization, works. Every man has plenty to do, and the responsible heads are so few in number that no opportunity to pass the buck into some other department or to jockey for favorable positions is offered.

I keep my own duties from being formal. I am not in direct charge of anything, but also I am in direct charge of everything. The only firm rule I have is to take up one thing at a time and to take up nothing else until my mind is free. I do not believe in quick decisions except in an emergency. I would rather take my time about making up my mind and nearly always manage to do so. Indeed, anything that can be decided in an instant is something that ought not to come to me.

My mail is read before it reaches me, and I see as little as I can of it, for I do not like to write letters. In fact, I have no period for dictation and my letters are nearly always personal. I do not write memoranda notes to members of the organization; we have stopped all that. I telephone the man or have him come in to see me if anything is to be discussed. All of this saves time. The writing of letters can be a great time-waster.—From Memoirs of Harvey S. Firestone, president of the Firestone Tire & Rubber Co., by Samuel Crowther in *System*.

ASTURIAS

IN view of the fact that she is the largest and most powerful motor vessel so far built, considerable interest is taken in the Asturias, now being completed for sea at Harland & Wolff's Belfast yard. This vessel is building for the Royal Mail Steam Packet Co., and will be employed—with a sister ship, the Alcantara, also being built by Harland & Wolff at Belfast—in the former company's trade between England and South America.

The main dimensions of the Asturias are: length 655 ft. 8 in., breadth 78 ft. and depth 45 ft., while her gross tonnage is 22,500. The total number of passengers and crew carried will be 1800. The hull is provided with 11 water-tight bulkheads forming 12 compartments, and is designed with a straight stem and a cruiser stern. The two pole masts fitted and the two short funnels give the vessel a particularly distinctive appearance. The Asturias will be propelled by two four-cycle, eight-cylinder, double-acting Diesel engines of the Harland-Burmeister & Wain type, developing 20,000 i.hp. when running at 115 r.p.m. and driving twin screws.

The passenger accommodation fully maintains the high standard of luxury that, notwithstanding the severe depression in the shipping industry, has been a marked characteristic of many vessels built within the last few years. Her maiden voyage will thus mark an epoch in the South-American service, as well as in marine engineering.—*Engineering* (London).

JANUARY COUNCIL MEETINGS

The sessions of the 1925 Council, held on Jan. 14, 25, 26, and 28, were attended by President Horning; Past-President Crane; Vice-Presidents Lítle, Carlson and Church; Councilors Brumbaugh, Burkhardt, Foster, Hunt, Rumney, and Warner; and Treasurer Whittelsey; and by F. F. Chandler, J. F. Winchester, Arthur Nutt, and O. W. Sjogren, members of the 1926 Council.

Ninety-one applications for individual membership were aproved. The resignations of 21 members were accepted, and 5 members were dropped for non-payment of dues that accrued Oct. 1, 1925. Nine reinstatements to membership were made; also 10 transfers in grade of membership.

The following were named as representatives of the Society on the Sectional Committee on Transmission Chains and Sprockets; D. B. Baker, W. J. Belcher, W. F. Cole, Charles Froesch and G. A. Young.

L. V. Pulsifer was appointed a representative on the National Safety Council Committee on Hazards of Spray Coating.

Organization Session of 1926 Council

The Organization Session of the 1926 Council was held in Detroit on Jan. 25, and was attended by President Lítle, Past-President Horning, First-Vice-President Hunt, Second-Vice-Presidents Sjogren and Nutt, Councilors Chandler, Warner and Winchester, and F. A. Whitten, chairman of the 1926 Standards Committee.

President Lítle announced the personnel of the 1926 administrative committees as follows:

CONSTITUTION COMMITTEE

A. J. Scaife, *Chairman*
H. M. Crane
C. M. Manly

FINANCE COMMITTEE

W. L. Batt, *Chairman*
A. J. Brosseau
H. L. Horning
H. A. Coffin
C. B. Whittelsey

MEETINGS COMMITTEE

L. C. Hill, *Chairman*
Carl Breer
V. P. Rumely
C. O. Guernsey
O. W. Sjogren
A. W. Herrington
W. B. Stout
R. R. Keith
C. E. Summers
H. O. K. Meister
F. E. Watts
J. F. Winchester

MEMBERSHIP COMMITTEE

H. L. Horning, *Chairman*
H. E. Coffin
John N. Willys
H. M. Crane
J. F. Winchester

PUBLICATIONS COMMITTEE

E. P. Warner, *Chairman*
L. C. Hill
S. W. Sparrow
W. E. Lay
John Younger

SECTIONS COMMITTEE

J. H. Hunt, *Chairman* (member at large)
J. W. White, Buffalo
F. M. Young, Milwaukee
T. Milton, Chicago
E. P. Warner, New England
E. Wooler, Cleveland
W. S. James, Northern California
V. G. Apple, Dayton
G. Walker Gilmer, Jr., Pennsylvania
G. L. McCain, Detroit
Eugene Power, Southern California
George Briggs, Indiana
A. W. Herrington, Washington
C. B. Veal, Metropolitan
R. E. Plimpton (member at large)
W. C. Keys (member at large)

Standards Committee

The names of the members who will serve this year as Chairmen and Vice-Chairmen of the Standards Committee and of its Divisions were reported. As indicated above, F. A. Whitten will be Chairman of the Standards Committee. K. L. Hermann and R. S. Begg will be the Committee Vice-Chairmen. The names of the Division Chairmen and Vice-Chairmen, as well as of those named by the Council for service this year on the various Divisions, will be listed in the March issue of THE JOURNAL.

Research Committee

The personnel of the Research Committee and of its Subcommittees was named as follows:

H. C. Dickinson, *Chairman*
B. B. Bachman
B. J. Lemon
O. C. Berry
T. J. Lítle, Jr.
H. M. Crane
E. H. Lockwood
H. L. Horning
C. M. Manly
H. A. Huebotter
Thomas Midgley, Jr.
J. H. Hunt
F. C. Mock
W. S. James
A. L. Nelson
C. F. Kettering
E. C. Newcomb
W. E. Lay
S. W. Sparrow
E. P. Warner

FUELS SUB-COMMITTEE

Division 1—Economic Aspects
(Cooperating with the American Petroleum Institute and the National Automobile Chamber of Commerce)
R. P. Anderson
O. C. Berry
B. B. Bachman
H. R. Cobleigh
H. M. Crane

Division 2—Specifications
(Cooperating with the American Society for Testing Materials and the Bureau of Standards)
H. L. Horning, *Chairman*
O. C. Berry
N. F. LeJeune
H. M. Crane
F. C. Mock
H. C. Dickinson
H. C. Mougey
C. F. Kettering
S. W. Sparrow
R. E. Wilson

HEADLIGHT SUB-COMMITTEE

(Cooperating with the Illuminating Engineering Society)
H. M. Crane
C. E. Godley
H. C. Dickinson
J. H. Hunt
R. N. Falge
T. J. Lítle, Jr.

HIGHWAYS SUB-COMMITTEE

(Cooperating with the Rubber Association and the Bureau of Public Roads)
B. B. Bachman, *Chairman*
R. W. Brown
B. J. Lemon
H. C. Dickinson
C. M. Manly
W. E. Lay
J. F. Winchester
S. H. Woods

LUBRICANTS SUB-COMMITTEE

(Cooperating with the American Petroleum Institute and the National Automobile Chamber of Commerce)
H. C. Dickinson
S. W. Sparrow
H. C. Mougey
R. E. Wilson

RIDING-QUALITIES SUB-COMMITTEE

H. C. Dickinson, *Chairman*
R. W. Brown
C. M. Manly
T. J. Lítle, Jr.
E. C. Newcomb
E. H. Lockwood
E. P. Warner

Applicants *Qualified*

The following applicants have qualified for admission to the Society between Dec. 10, 1925, and Jan. 11, 1926. The various grades of membership are indicated by (M) Member; (A) Associate Member; (J) Junior; (Aff) Affiliate; (S M) Service Member; (F M) Foreign Member.

ALTORFER, A. W. (A) vice-president and chief engineer, Altorfer Bros. Co., *Peoria, Ill.*

BAEZ, FIRST LIEUT. RAPHAEL, JR. (A) Air Service, Chanute Field, *Rantoul, Ill.*

BARNES, SWIFT C. (A) sales manager, Walden-Worcester, Inc., *Worcester, Mass.;* (mail) 38 South Lenox Street.

BOULT, THOMAS CHRISTOPHER (A) engineer, Morris Motors, Ltd., Cowley, near Oxford, England; (mail) 13 Southfield Road, *Oxford, England.*

BREMER, FRED G. (A) chief engineer, U. S. Chain & Forging Co., 575 Union Trust Building, *Pittsburgh.*

BROCK, ARTHUR, JR. (M) owner and general manager, Arthur Brock, Jr., Tool & Mfg. Works, 533 North 11th Street, *Philadelphia.*

BROWNE, ROYAL S. (A) instructor of automobile mechanics, Lake View High School, *Chicago;* (mail) 4118 North Redvale Avenue.

BRYANT, OSWALD (A) engineer and tester, Skurray's Motor Engineers, Swindon, England; (mail) 17 Plymouth Street, *Swindon, Wiltshire, England.*

CATHCART, CHARLES D. (A) chief draftsman and assistant engineer, National Automatic Pan Corporation, *Los Angeles;* (mail) 1139 West 69th Street.

CHARLES, H. N. (A) engineer, Morris Motors, Ltd., Cowley, near Oxford, England; (mail) 14 Lime Walk, *Highfield, Oxford, England.*

COWAN, H. W. (A) sales manager, Charles A. Strelinger Co., 149 East Larned Street, *Detroit.*

CRITTENDEN, P. L. (M) chief engineer, National Brake & Electric Co., *Milwaukee.*

CROWLEY, J. W., JR. (M) aeronautical engineer, National Advisory Committee for Aeronautics, Langley Field, *Hampton, Va.*

DAVEY, CLARENCE G. (M) chief draftsman, A. C. Spark Plug Co., *Flint, Mich.;* (mail) 602 Paterson Street.

EHRICH, E. H. (A) master mechanic, Sparks-Withington Co., *Jackson, Mich.;* (mail) 746 Douglas Street.

ELLIS, EMMETT S. (A) tool engineer, Motor Wheel Corporation, Lansing, Mich.; (mail) 1622 Fourth Street, *Jackson, Mich.*

ELSER, CHRIS H. (M) chief engineer, Covert Gear & Mfg. Corporation, *Lockport, N. Y.*

ENDICOTT, JAMES LAWRENCE (A) designing engineer and plant manager, Diatomaceous Products Co., Inc., *City of Washington;* (mail) 1673 Columbia Road.

ESKIL, WILLIAM A. (J) sales engineer, Electric Power Equipment Corporation, New York City; (mail) 405 Jamaica Avenue, *Long Island City, N. Y.*

ETTER, E. L. (A) special representative, Studebaker Corporation of America, South Bend, Ind.; (mail) The Arizona, *Phoenix, Ariz.*

FOULOIS, LIEUT-COL. B. D. (A) Air Service, Mitchel Field, *Garden City, N. Y.*

FRAZZA, J. F. (A) service manager, Saskatchewan Motor Co., Ltd., *Saskatoon, Sask., Canada.*

GASKILL, FERRIS D. (A) production superintendent, Yellow Truck & Coach Mfg. Co., *Chicago;* (mail) 1642 North Natchez Avenue.

GRASSI, BRUNO (J) mechanical and electrical engineering student, Grassi & Cia, *Sao Paulo, Brazil;* (mail) Alameda Barao de Limeira 125.

GRIMSHAW, ROBERT S. (M) body designer and color artist, Deitrich, Inc., division of Murray Body Co., 868 Blaine Avenue, *Detroit.*

GRUSE, W. A. (M) director of petroleum investigations, Mellon Institute of Industrial Research, *Pittsburgh.*

HAMBURGER, PIERCE (A) inspector of motor vehicles, Brooklyn Union Gas Co., 208 Third Avenue, *Brooklyn, N. Y.*

HARPER, WILLIAM DAVID (A) inventor and engineer on inventions, Harper Hanger Co., Boston; (mail) 29 Riverdale Road, *Wellesley Farms, Mass.*

HENDRIE, G. S. (A) sales manager, Detroit Gear & Machine Co., 670 East Woodbridge Street, *Detroit.*

HOOVEN, FRED J. (J) student, Massachusetts Institute of Technology, *Cambridge* 39, *Mass.*

HUFF, LEO (A) motor transport engineer, Pure Oil Co., Columbus, Ohio; (mail) 3190 South Grand Boulevard, *St. Louis.*

KINCAID, FRANK M. (M) chief engineer, Commerce Motor Truck Co., *Ypsilanti, Mich.;* (mail) 413 Ballard Street.

KLEIN, ARTHUR HAYS (A) service superintendent, Greer-Robbins Co., Los Angeles; (mail) 129 South Almont Drive, *Beverly Hills, Cal.*

KLEIN, EDWARD R. (J) designer, Sheldon Axle & Spring Co., *Wilkes-Barre, Pa.;* (mail) 222 North Pennsylvania Avenue.

KNEIP, LIEUT. J. B. (S M) Naval Air Station, *San Diego, Cal.*

LENZ, PETER (A) mechanical engineer and designer, small motor engine department, Westinghouse Electric & Mfg. Co., *East Pittsburgh, Pa.*

LIVINGSTONE, C. J. (J) assistant fellow, Mellon Institute of Industrial Research, *Pittsburgh.*

LYONS, JOSEPH H. (A) manager, City Transportation Co., *Dash Point, Wash.*

MENGEL, FRED E. (J) service engineer, Edmunds & Jones Corporation, 4440 Lawton Avenue, *Detroit.*

MONFORT, GEORGE J. (M) chief draftsman, Chrysler Corporation, *Detroit;* (mail) 3732 Vicksburg Avenue.

ORELUP, J. W. (A) research director, Chemical Co. of America, *Springfield, N. J.;* (mail) P. O. Box 197.

OSBORN, PAUL VICTOR (A) control manager, Continental Motors Corporation, Detroit; (mail) Continental Motors Corporation, *Muskegon, Mich.*

PENFIELD, W. S. (M) superintendent of shops, Associated Oil Co., *San Francisco.*

PIROOMOFF, GEORGE S. (M) transportation engineer, executive staff, White Motor Co., 842 East 79th Street, *Cleveland.*

POMEROY, THEODORE (A) president and treasurer, K. P. Products Co., Inc., 60 Beaver Street, *New York City.*

PORSCHE, DR. FERDINAND (F M) director and technical manager, Daimler Motoren Gesellschaft, Stuttgart-Unterturkheim (Mercedes), Germany; (mail) *Stuttgart, Feuerbacherweg* 48, *Germany.*

PRALL, B. R. (A) buyer, Montgomery Ward & Co., *Chicago;* (mail) 2145 Lunt Avenue.

PSCHAIDEN, A. L. (J) draftsman, Graham Bros., *Evansville, Ind.;* (mail) 501 Line Street.

REINHART, HOWARD A. (A) Automotive Tool & Sales Co., *Oakland, Cal.;* (mail) 2815 Best Avenue.

SCOFIELD, CARL R. (J) detail checker, Burroughs Adding Machine Co., *Detroit;* (mail) 2511 Lothrop Avenue.

SPRADBROW, NORMAN H. G. (A) production manager, Harmer-Knowles Truck Corporation, Ltd., *Toronto, Ont., Canada;* (mail) 9 Watford Avenue.

STALKER, EDWARD A. (M) assistant professor of aeronautical engineering, University of Michigan, *Ann Arbor, Mich.;* (mail) 1923 Geddes Avenue.

STERLING, LEROY P. (A) 819 Fifth Street, *Miami Beach, Fla.*

STRICKLAND, HERBERT (M) mechanical engineer, Ford Motor Co. of Canada, Ltd., Ford, Ont., Canada; (mail) 848 Hall Avenue, *Windsor, Ont., Canada.*

TAYLOR, EARL A. (M) works manager, Yellow Sleeve Valve Works, Inc., East Moline, Ill.; (mail) 2740 15th Avenue, *Moline, Ill.*

TAYLOR, JOHN H. (A) foreman of experimental department, Cleveland Automobile Co., Euclid Avenue, *Cleveland.*

WOODRING, PAUL M. (A) sales engineer, Vacuum Oil Co., *Philadelphia;* (mail) 1941 67th Avenue.

Applicants *for* Membership

The applications for membership received between Dec. 15, 1925, and Jan. 15, 1926, are given below. The members of the Society are urged to send any pertinent information with regard to those listed which the Council should have for consideration prior to their election. It is requested that such communications from members be sent promptly.

AGLER, WILLIAM B., district mechanic, Associated Oil Co., *Los Angeles.*

ALLEN, HENRY BUTLER, chief metallurgist, Henry Disston & Sons, Inc., *Tacony, Philadelphia.*

ANDERSON, HARRY W., 672 Fort George Avenue, *New York City.*

ASPELL, THOMAS A., sales department, B. F. Goodrich Rubber Co., *Akron, Ohio.*

BALLARD, J. H., superintendent, Acme Motor Truck Co., *Cadillac, Mich.*

BANKS, S. J. E., general manager, Automobiles M. Berliet, *Twickenham, near London, England.*

BECKMANN, M. A., engineer, Kant-Skore Piston Co., *Cincinnati.*

BISSELLE, WILLIAM J., manager of equipment department, Fleischmann Co., *New York City.*

BITNER, EDWARD H., supervisor of motor vehicles, Bell Telephone Co. of Pennsylvania, *Harrisburg, Pa.*

BLUME, WILLIAM A., engineer, American Brake Shoe & Foundry Co., *New York City.*

BOLLIER, JACOB, designer and engineer, Keystone Steel & Wire Co., *Peoria, Ill.*

BUNDY, HARRY W., president and general manager, Bundy Tubing Co., *Detroit.*

BURGESS, LAURENCE E., experimental engineer, International Motor Co., *Allentown, Pa.*

CANDLER, D. W., general manager, Holley Carbureter Co., *Detroit.*

CARTER, FLOYD B., mechanical engineer, Fate-Root-Heath Co., *Plymouth, Ohio.*

COLEMAN, HENRY B., secretary and sales manager, Hoopes Bros. & Darlington, Inc., *West Chester, Pa.*

CONDON, ROBERT S., draftsman, Kearney & Trecker Corporation, *Milwaukee.*

CRABTREE, LEONARD L., chief chemist and textile engineer, Salt's Textile Mfg. Co., *Bridgeport, Conn.*

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